GEOLOGY OF THE PRINCETON QUADRANGLE

STUART WELLER

The
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WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST

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Geology of the Princeton Quadrangle

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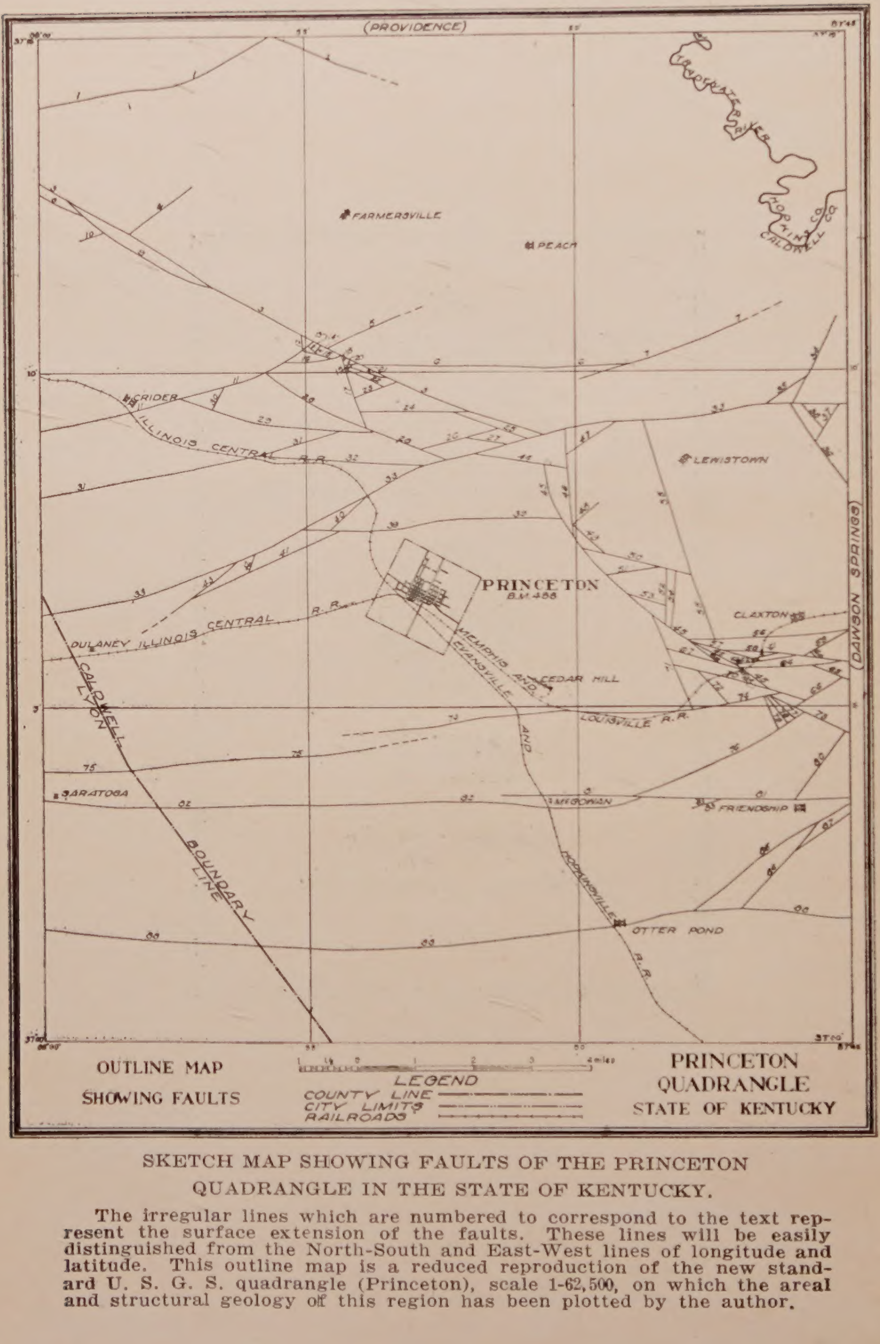

SKETCH MAP SHOWING FAULTS OF THE PRINCETON QUADRANGLE IN THE STATE OF KENTUCKY.

The irregular lines which are numbered to correspond to the text represent the surface extension of the faults. These lines will be easily distinguished from the North-South and East-West lines of longitude and latitude. This outline map is a reduced reproduction of the new standard U. S. G. S. quadrangle (Princeton), scale 1-62,500, on which the areal and structural geology off this region has been plotted by the author.

GEOLOGY *of the* PRINCETON QUADRANGLE

A Detailed Report on the Stratigraphy and Structure of the Princeton, Kentucky Region

BY

STUART WELLER
ASSISTANT GEOLOGIST

Presented With Four Separate Miscellaneous Papers

BY

ARTHUR MCQUISTON MILLER
WILBUR GREELEY BURROUGHS
ADOLPH CHARLES NOE *and*
WILLARD ROUSE JILLSON

Illustrated with Forty-two Photographs,
Maps and Diagrams

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Letter of Transmittal

Dr. W. R. Jillson,
Director and State Geologist,
The Kentucky Geological Survey,
Frankfort, Kentucky.

Dear Sir:—

I am transmitting herewith the manuscript of a report on the stratigraphic and structural Geology of the Princeton Quadrangle of the United States Geological Survey topographic atlas.

This is the second quadrangle lying within the highly faulted area of western Kentucky which includes the important fluorspar deposits of the State, upon which I have reported. The first of these reports was upon the Golconda Quadrangle, and a third upon the Cave in Rock Quadrangle, including most of the important mining area of Crittenden County, will be made later. Nearly the whole of the area covered in the present report is included in Caldwell County. The careful and accurate mapping of the structure and stratigraphy of these areas will undoubtedly prove to be of very great assistance in further prospecting and development in the Western Kentucky fluorspar field.

Respectfully submitted,

Stuart Weller.

The University of Chicago,
Chicago, Ill.
Oct. 1st, 1922.

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GEOLOGY *of the*
PRINCETON QUADRANGLE

I.

GEOLOGY *of the* PRINCETON QUADRANGLE

By STUART WELLER, *Assistant Geologist*

CHAPTER I.

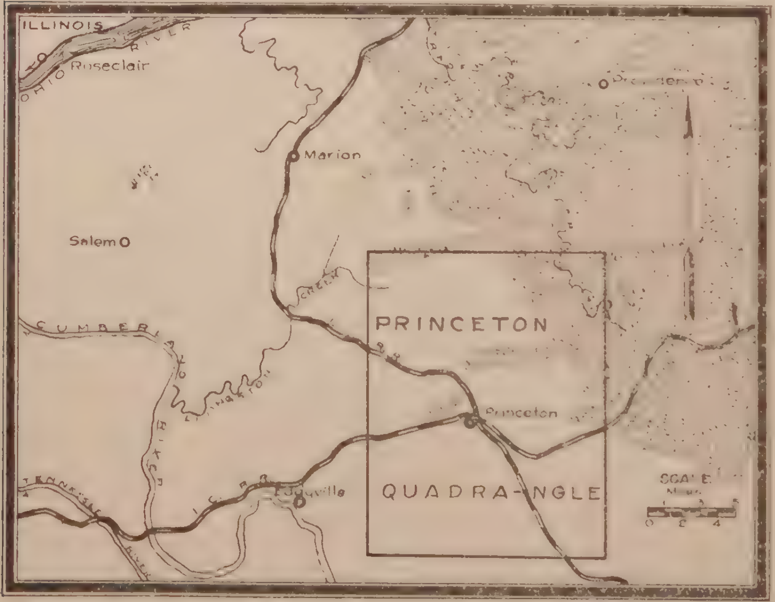
INTRODUCTION

The Princeton Quadrangle of the United States Geological Survey Atlas of topography, lies between longitude 87° 45′ and 88°, and between latitude 37° and 37° 15′. It covers about 240 square miles, all but about 22 miles of which is included in Caldwell County. The smaller portion, in the southwestern corner of the quadrangle, lies in Lyon County.

Nearly the entire of the area is extensively faulted. The most complicated faulting lies along a belt extending in a northwest direction from a little south of Claxton, near the eastern border of the quadrangle, to the western border about two and one-half miles south of the northwestern corner. Apart from the faulting in this belt, where the direction of individual faults is in nearly every point of the compass, the major faults are for the most part in a general east-west direction. None of this faulting is reflected to any great extent in the topography of the area. In places drainage lines have been developed along fault lines, and after the structure is worked out, the faults are found locally to follow ravines and gullies in many places, but there are no outstanding topographic characteristics which would suggest to the observer of the topographic may alone that the area is complexly faulted. The southwestern portion of the area, about one-fourth or a little more of the whole, is rather sharply differentiated topographically from most of the remaining part of the quadrangle, by reason of the presence of great numbers of sink holes. These sinks are largely characteristic of the Ste. Genevieve limestone. Aside from the sink hole area the topography is essentially mature in its stage of development, being fully dissected. In places where the less resistant limestone and shale beds constitute the surface formations, the topographic expression is somewhat soft, but elsewhere it is decidedly rugged.

The town of Princeton, with about 3,689 inhabitants, is the County Seat of Caldwell County, and is situated near the center of the Quadrangle. A number of other villages, consisting of one or more stores and a few houses, are scattered through the area. Of these Crider, Farmersville, Cedar Hill are perhaps the most important. Smaller villages are Flat Rock, Rufus, Lewistown, Olney, Claxton, Dulany, Scottsburg, McGowan, Otter Pond, and Saratoga.

Nearly the entire area is drained by comparatively small streams. Tradewater River crosses the northwestern corner of the Quadrangle, and approximately one-half of the entire quadrangle drains into this stream through Flynn and Donaldson Creeks and their tributaries. The more southern portion of the area, separated by an irregular, northwest-southeast line, following in the main the southern border of the more faulted belt, drains into the Cumberland River through Eddy Creek and its tributaries, and White Sulphur Creek.



Sketch map of a portion of Western Kentucky and Illinois showing the geographical position of the Princeton Quadrangle. The white area is Mississippian except west of the Tennessee River. Coal Measures cover the stippled areas.

In the State of Kentucky it is much more difficult to describe the exact location of specific points, than in the states where the federal land surveys have subdivided the surface into townships and sections. Where these subdivisions have been made it is a simple matter to describe the location of a given point within the limits of a 40-acre tract, or even within the limits of a 10-acre tract. This cannot be done where such land surveys do not exist. The Kentucky quadrangles are divided, however, into nine smaller quadrangular areas by the 5-minute lines of longitude and latitude, and for the purpose of assisting in describing locations, some nomenclature of these smaller quadrangles is convenient. In the present report these smaller units will be designated as rectangles to distinguish them from the quadrangle as a whole, and each will be designated by the name of some geographic feature present in that particular unit. Beginning at the northeast corner of the quadrangle map, the rectangles will be designated as follows: first, the Tradewater rectangle, so-called from the presence of the river of that name, which does not enter any other rectangle on the map; second, next west of the Tradewater is the Farmersville rectangle; third, next west of the last is the Flat Rock rectangle; fourth, south of the last is the Crider rectangle, to the east of which; fifth, is the Princeton rectangle; sixth, east of the Princeton is the Claxton rectangle; seventh, south of the Claxton is the Otter Pond rectangle; eighth, west of the Otter Pond is the McGowan rectangle; and ninth, west of the McGowan, in the southwest corner of the map, is the Saratoga rectangle.

The field work upon which this report is based was carried on throughout the whole of the 1921 field season, and during a part of 1922. In the prosecution of the work the writer has been most efficiently assisted by Mr. Ben B. Cox. The same assistant has also rendered great service in his study, under the writer's direction, of the fossil collections from the region, and in the compilation of the several lists of fossils which are included in the report. For the identification of the fossil bryozoans in the several faunas, acknowledgment is due Mr. A. C. McFarlan, who has been engaged for a number of years in a very detailed study of the bryozoans of the Chester faunas. Throughout the progress of the work Dr. Jillson, Director of the Kentucky Geological Survey, has done much to facilitate the investigation.

CHAPTER II.

STRATIGRAPHIC GEOLOGY, FORMATIONS NOT EXPOSED AT THE SURFACE

INTRODUCTION

The hard rock geologic formations which are exposed at the surface in the Princeton quadrangle are all Mississippian and Pennsylvanian in age. The oldest exposed formation is the Spergen or Salem limestone, whose position is somewhat above the middle of the Lower Mississippian or Iowa Series. The remaining higher units of the Iowa Series are all well exhibited within the quadrangle, and also the whole of the Upper Mississippian or Chester Series. The Pennsylvanian is represented only by strata of Pottsville age.

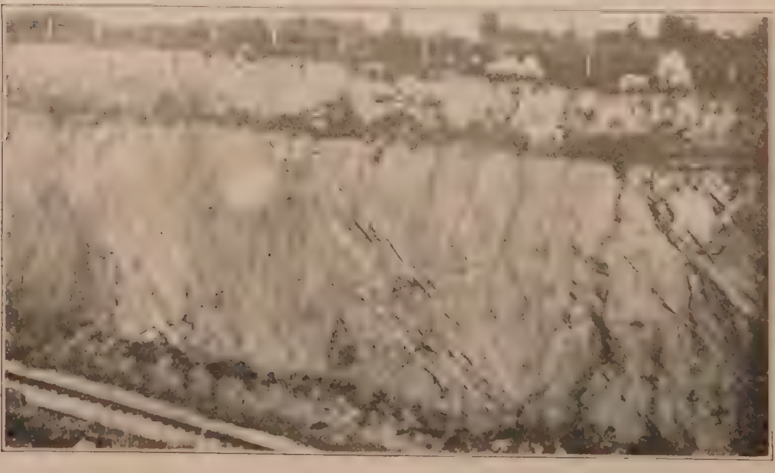
Although no formations older than the Spergen or Salem limestone are exposed at the surface, the succession of beds down to and including some portion of the Devonian, has been made known by the drilling of a deep well near Cedar Hill, on the farm of Mrs. W. F. O'Hara. This well was drilled during the year 1921, and a fairly complete series of cuttings from the different depths has been preserved by Mr. F. K. Wylie, of Princeton. These cuttings have been generously placed in the hands of the writer, who is under great obligation to Mr. Wylie for the privilege of studying them. The depth of the well is 2,017 feet, and the strata penetrated are as follows:

Log of Well at Cedar Hill, Kentucky

Iowa Series (Lower Mississippian)	Thickness.	Depth.
No samples	250	250
Gray limestone, more or less crystalline, with chert	5	255
No samples	55	310
Dark and light gray limestone, more or less crystalline, with chert	240	550
Black, silico-calcareous shale	10	560
Dark, silico-calcareous shale with some gray limestone	25	585
Brown limestone with chert and pyrite	65	650
Brown to gray limestone with chert and pyrite	30	680
Gray and brown limestone with chert and pyrite	350	1030

Brown limestone with some silico-calcareous shale, some chert and pyrite	70	1100
Dark to black silico-calcareous shale with some pyrite, no chert	502	1602
Black, silico-calcareous shale, more siliceous than above	8	1610
Black, silico-calcareous shale with some gray limestone	5	1615
Greenish black, highly siliceous shale	10	1625
No sample	5	1630
Chattanooga Shale (Devonian)		
Brown to black shale with Sporangites	135	1765
Black siliceous shale with conspicuous pyrite bed at 1835	107	1872
Devonian Limestone		
White crystalline limestone	10	1882
Gray chert with some white limestone	33	1915
No sample	95	2010
White to dark gray limestone with some chert. Fragment of Favosites	......	2010
White crystalline limestone with some darker fragments	......	2017

The top of the well is at an elevation of approximately 490 feet above sea level. In the Cedar Hill quarry, about one-half mile northeast of the well, the contact between the Ste. Gene-



DETAIL OF HARDINSBURG SANDSTONE.

Shaly Hardinsburg Sandstone, Walche's Cut, Illinois Central Railroad, east of Scottsburg.

vieve limestone, the uppermost formation of the Lower Mississippian or Iowa Series, with the overlying Renault limestone of the Chester Series, is at an elevation of 500 feet, a difference of 6 feet. However, the interval between the top of the well and the top of the Ste. Genevieve limestone is somewhat greater than this because of the gentle dip of the beds to the northeast, and it is assumed that 70 feet of Ste. Genevieve limestone should be present above the ground at the location of the well. This thickness, added to 1,630 feet, the depth of the well to the top of the Chattanooga shale, gives a thickness of 1,700 feet for the entire Iowa Series, which is considerably greater than has been recorded in the Ohio and Mississippi Valleys.

In the typical section of the Iowa Series as exhibited in the Mississippi Valley, the following formations are recognized:

Ste. Genevieve limestone.
St. Louis limestone.
Spergen or Salem limestone.
Warsaw limestone and shale.
Keokuk limestone.
Burlington limestone.
Kinderhook Group.

In the Cedar Hill well section it is not possible to draw any sharp lines of demarkation between the several units of the typical section, although the three uppermost formations are distinctly recognizable in the surface outcrops. The nearest area in which these lower formations are exposed at the surface is in Hardin County, Illinois, about the Hicks dome, but the Cedar Hill section is considerably greater than the estimated thicknesses of the several recognized units in Hardin County, but, as might be expected, the lithology is perhaps somewhat more like that of Hardin County than that of the more typical Mississippi River section.

DEVONIAN

Devonian Limestone. The Cedar Hill well penetrates to a depth of 2,017 feet, the lower 145 feet being in beds beneath the Chattanooga shale. So far as samples have been saved, the whole of this is a limestone formation, that portion between

1882 and 1915 being largely a gray chert with a lesser amount of white limestone. Samples from other beds show that the limestone is prevailingly light colored, much of it very white and crystalline. The sample from the depth 2,010 is somewhat darker than the others, being a mixture of white limestone and darker gray limestone with some chert. At the bottom of the well the limestone is again lighter in color. The position of this limestone directly beneath the Chattanooga shale suggests that its age is equivalent to that of the limestones which lie beneath that formation elsewhere in the Ohio Valley. The contact between the Chattanooga shale and the underlying limestone is exposed at the surface in southern Ohio and Indiana, in Kentucky south from Louisville and elsewhere, in Hardin County, Illinois, and again in Union County, Illinois, near the Mississippi river. Wherever this contact is known the subjacent formation is a limestone of Middle Devonian age, and in all probability the limestone in the Cedar Hill well is of the same age. A more exact correlation cannot be attempted with the available data. In one of the well samples, at the depth of 2,010 feet, a fragment of a species of the coral genus Favosites has been detected, and while this is not conclusive, it is in full harmony with the Middle Devonian age of the bed.

Chattanooga Shale. One of the most persistent formations throughout the Ohio Valley, extending northward in Ohio, Indiana and Illinois, southward along the Appalachians, and westward as far as Oklahoma, is the Chattanooga shale. The formation has been described under various names[1], but wherever the proper portion of the geologic column outcrops, the shale occurs. It is also uniformly met with throughout this area, in wells, where younger formations are present at the surface. The formation is very uniform in its lithologic characters, being a dark brown or black, fissile shale, with hard layers or lenses in places, which are likely to be more or less charged with pyrite. A very characteristic feature of the shale is the presence, in greater or less abundance, of the empty spore cases of an extinct plant, called Sporangites. These little bodies are circular and disk-like in form, of small size, being only a fraction of a millimeter in diameter, and brown or resinous in color and appearance. These characteristic sporangites are present in some of the chips taken from the Cedar Hill well, and the lithologic character of the chips corresponds with that of the surface exposures of the formation.

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[1] See Ill. State Geol. Surv., Bull. No. 41, p. 87 (1921).

The thickness of the Chattanooga shale in the Cedar Hill well is 242 feet, which is considerably greater than has been recorded elsewhere in Kentucky. In Jefferson County Butts reports a thickness of 100 feet.[2] In a number of wells in Warren County the thickness of the black shale varies from 21 to 185 feet, while in Allen County the thickness is commonly between 40 and 50 feet, although extremes of 9 and 116 feet are reported.[3] The thickness of the shale in the Cedar Hill well is less, however, than has been reported from Hardin County, Illinois, where the formation has an estimated thickness of 400 feet.[4]

MISSISSIPPIAN

The lower formational units of the typical Iowa Series of the Mississippian cannot be fully differentiated as such, in the Cedar Hill well. Lying just above the Chattanooga shale there is a black to greenish, highly siliceous shale bed, probably 15 feet in thickness, above this for five feet there are some fragments of gray limestone in the drill cuttings, associated with black, silico-calcareous shale. Overlying these lower beds there is a little more than 500 feet of dark, mostly black, silico-calcareous shales. Throughout this thickness the fragments present in the well samples effervesce freely in hydrocloric acid, but leave a large insoluble residue, some part of which seems to be fine siliceous grains. The fragments in the samples of cuttings are more or less flake-like, resembling shale. These beds probably cannot be considered as limestone, although a considerable proportion of calcium carbonate is present, but rather as a calcareous and siliceous shale. The bed might also be looked upon as an impure, siliceous limestone. Lithologically these beds are conspicuously different from any of the Kinderhook, Burlington and Keokuk strata of the typical section, although their position would indicate their equivalence with these lower formations of the Iowa Series. These beds perhaps resemble more closely that portion of the Mississippian section in Hardin County, Illinois, which has been referred to the Osage.[5] The Osage in Hardin County is poorly exposed, being

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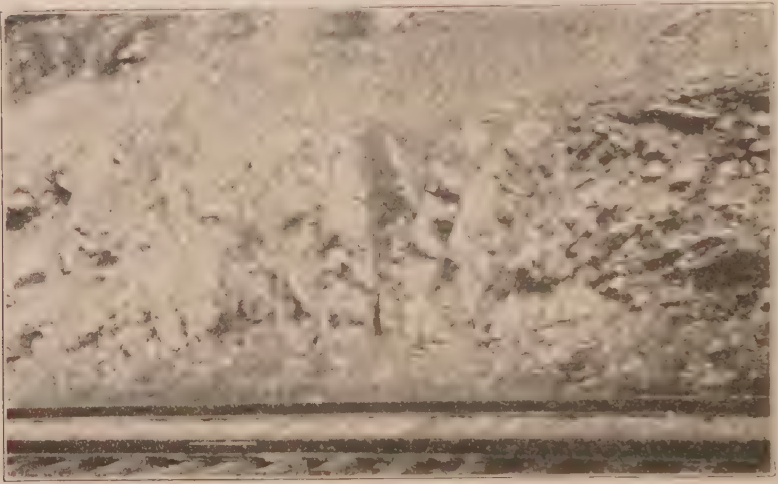
[2] Ky. Geol. Surv., Ser. 4, Vol. 3, pt. 2, p. 130 (1915).
[3] Ky. Geol. Surv., Ser. 5, Bull. No. 1, pp. 179-191 and 504-516 (1920).
[4] Ill. State Geol. Surv., Bull. No. 41, p. 92 (1921).



INTENSE LOCAL DEFORMATION.

These greatly contorted beds of Paint Creek Limestone adjacent to the main fault in Walche's Cut, indicate to what degree the original bedding of the sediments of the Princeton Quadrangle has been altered. The significance of such a degree of deformation is at once apparent.

represented almost entirely by broken residual chert upon the surface. Some portions of the chert resemble a fine grained sandstone, and originally may have been a siliceous limestone in which the silica occurred in the form of very fine quartz grains. The chert in Hardin County is believed to be only a superficial development at or near the surface, and the formation may be much like that in the Cedar Hill well where it is deeply buried. The computed thickness of these beds in Hardin County is 550 feet, which compares favorably with the thickness present in the Cedar Hill well.

Overlying the dark, impure limestone or silico-calcareous shale which possibly represents the Osage division of the Iowa Series, the Cedar Hill well samples are essentially all limestones, from brown to light and dark gray in color, and most of them include numerous fragments of chert, so that the entire thickness of strata, down to the depth of 1,100 feet, seems to have been a series of more or less cherty limestones. If the beds below these limestones are equivalent of the Osage, then these cherty limestones are the equivalents of the Warsaw, Spergen or Salem, St. Louis, and Ste. Genevieve limestone formations. The three higher units mentioned are exposed at the surface within the Princeton Quadrangle, the St. Louis and Ste. Genevieve limestones being extensively exposed. None of the samples of cuttings from the well seem to have been taken from the Ste. Genevieve limestone, but the first sample was taken at a depth of 250 feet, which would permit a thickness of over 300 feet for that formation, which is the estimated thickness in this general region. The drill cuttings from the lesser depths of the well, that have been saved, are of a lithologic character to be expected from the St. Louis limestone, but the basal limits of the formation cannot be established. If a thickness of 350 feet be allowed for the St. Louis, added to approximately 250 feet of Ste. Genevieve limestone, a thickness of 500 feet remains between these beds and top of the silico-calareous shale or impure limestone which sets in at about 1100 feet, such a thickness is greatly in excess of any observed thickness of the Spergen and Warsaw formations, these beds being estimated at 250 feet in Hardin County, Illinois.[6] In all probability the St. Louis limestone in the section is considerably thicker than the suggested 350 feet, perhaps as much as 500 feet, but there is no evidence afforded by the samples of drill cuttings whereby the base of the St. Louis limestone can be certainly fixed, nor is there any basis for the identification of the Spergen or Salem limestone, although the equivalents of these formations must be present in the section.

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[5] Ill. State Geol. Surv., Bull. No. 41, p. 92 (1921).

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[6] Ill. State Geol. Surv., Bull. No. 41, p. 99 (1921).

CHAPTER III.

STRATIGRAPHIC GEOLOGY, IOWA SERIES

Introductory Statement. The hard rock formations exposed at the surface within the Princeton quadrangle are all Mississippian and Pennsylvanian in age. The oldest of the exposed formations is the Spergen or Salem limestone, the youngest one being of Pottsville age, in the lower Pennsylvanian. In addition to these, however, a formation consisting of unconsolidated gravel, probably of late Tertiary age, caps some of the high hills in the western and southwestern portion of the quadrangle. The several formations will be considered in order, beginning with the oldest one.

The formations of the Mississippian System are divisible into two series, which have been referred to many times in the literature as Lower and Upper Mississippian. The Upper Mississippian has long been known as the Chester formation or group, but the investigations of recent years have shown that the Chester is deserving to rank as a distinct Series, made up of many different formations. The Lower Mississippian has long been subdivided into a number of more or less well defined formations, but only recently has there been a distinct Series name applied to the whole succession of formations, the name so used being the Iowa Series,[1] adopted because the more typical section of the series is exposed in the southeastern portion of that state, and in the adjacent portions of Illinois and Missouri, and because the section was first worked out in detail by James Hall during his work as State Geologist of Iowa.

The Iowa Series is subdivided into the Kinderhook, the Osage, and the Meramec Groups, formations of the last of these groups only being exposed within the limits of the Princeton Quadrangle.

Spergen or Salem Limestone

Name. The early collectors of fossils in Indiana discovered a locality near Salem, in Washington County, where great numbers of small fossils occurred in an oolitic limestone. This locality came to be known as Spergen Hill or Spurgeon's Hill by the local collectors, doubtless from the name of the property owner of the locality, but the name never has had any standing as a recognized geographic term, and is not to be found upon any map. The fossils from this locality came to be known as the Spergen Hill fauna, but were always referred to either the Warsaw or the St. Louis formation. Spergen Hill or Spergen was never used as a true formation name until it was proposed by Ulrich. In 1897 Hopkins and Siebenthal [2] published a report on "The Bedford Oolitic Limestone of Indiana," in which they proposed to use the name Bedford limestone for the formation in question. It has been shown by Prosser,[3] however, that the name Bedford had been applied by Newberry in 1870 to one of the geological subdivisions in Ohio, and consequently was preoccupied at the time it was proposed by Hopkins and Siebenthal for this Indiana formation. Siebenthal [4] later claimed that the name Bedford had been used for the Indiana formation as early as 1862 by Richard Owen, but it seems clear that Owen's use of the name was not intended as a formation name as such names are now used. In 1901 Cumings [5] proposed to substitute the name Salem for the Indiana formation including the Bedford building stone, and with the elimination of Bedford because of its prior use in Ohio, this seems to be the first legitimate name given to the formation. In 1904 Ulrich [6] first applied the name Spergen Hill limestone to the formation, this name being exactly equivalent to the Salem limestone of Cumings. In 1905 Ulrich [7] again used the name in the same sense, but contracted it to Spergen limestone.

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[1] Weller, Jour. Geol., Vol. 28, p. 282 (1920 .

From the standpoint of priority the name Salem should be used for this formation, but the Committee on Geologic Names of the United States Geological Survey has seen fit to adopt Spergen, in consequence of which the latter name has been more widely used in the literature than Salem. In the present report the formation will be referred to as the Spergen or Salem limestone.

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[2] 21st Rep. Dept. Geol. and Nat. Res. Indiana, pp. 289-427.

[3] Jour. Geol., Vol. 9, p. 215 (1901); also Geol. Surv. Ohio, 4th Ser., Bull. No. 7, p. 19 (1905).

[4] Jour. Geol., Vol. 9, pp. 234-235 (1901).

[5] Jour. Geol., Vol. 9, p. 232 (1901).

[6] Prof. Paper, U. S. Geol. Surv., No. 24, table opp. p. 90; also Mo. Bureau Geol. and Mines, Vol. 2, 2nd Ser., p. 110.

[7] Prof. Paper, U. S. Geol. Surv., No. 36, p. 28.

Distribution. The Spergen or Salem limestone has a very limited area of outcrop within the Princeton Quadrangle. It is exposed along the Evansville branch of the Illinois Central Railroad, about one and one-half miles northwest of the station at Princeton, just north of fault No. 38. One of the best outcrops of the formation is west of the Farmersville road, opposite the exposure along the railroad just mentioned, in the side of the private road, only a few rods from the public highway. The entire area of outcrop of the formation at this place is small, being only a fraction of a square mile, with but few actual exposures, although it can be recognized over most of the area from the scattered residual material.

Lithologic character. Although the Spergen or Salem beds have been completely silicified in all surface exposures observed, they have not been changed to a true chert. All of the original structures of the limestone, the bedding, the organic remains, etc., have been retained. The silicified rock is very porous, and in the weathered portion, at least, it is a light, reddish-brown color. The rock is composed almost exclusively of fragments of fossils, but any complete specimens are rare.

Thickness. The full thickness of the Spergen or Salem has nowhere been observed in the area under consideration. There is room for a maximum exposure of about 40 or 50 feet beneath the St. Louis limestone, in the area where the formation is present at the surface in the Princeton Quadrangle, but it is not possible to determine how much deeper it extends. In the deep well at Cedar Hill the Spergen or Salem is undoubtedly present, but it has not been possible to recognize it as such or to distinguish it from the underlying or overlying members of the Series of formations, so there is no check on its thickness at that point. In the Mississippi Valley south from St. Louis the thickness of the formation does not vary greatly from 160 feet, although it is much thinner than this in southern Iowa, and also in the Indiana region where it was originally described. The formation has not been well differentiated from the underlying Warsaw in Hardin County, Illinois, but a limestone stratum of about 60 feet may be the equivalent of the formation.[8] In sections elsewhere, especially in the Mississippi Valley and in Indiana, a considerable portion of the Spergen or Salem formation is more or less oolitic in texture, but this characteristic has not been observed near Princeton.

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[8] Ill. State Geol. Surv., Bull. 41, p. 100 (1921).

Stratigraphic relations. There is no evidence of any stratigraphic break within the Iowa Series of the Mississippian in this portion of Kentucky. Sedimentation seems to have continued without interruption throughout the entire epoch, which condition accounts for the absence of unconformities between the several formational units, and also constitutes one of the reasons why it is so difficult to draw any lines of sharp demarkation between the formations.

Paleontology. The outcrops of the Spergen or Salem, and also the residual material, are composed largely of organic remains, but good fossils are not common. As yet no thorough search has been made for a representative fauna, but a fairly good example of *Melonechinus* sp. and one of *Dizygocrinus* sp. have been picked up among the residual fragments of the formation.

Correlation. The correlation of the beds referred to the Spergen or Salem limestone in the Princeton Quadrangle is based largely upon their stratigraphic position beneath St. Louis limestone. The crinoid *Dizygocrinus* sp. closely resembles species described as coming from the St. Louis limestone in Washington County, Indiana, but at the time it was defined, the Spergen beds were commonly included with the St. Louis, and the type specimen undoubtedly came from true Spergen or Salem; no closely related species is known from beds that are truly St. Louis. *Melonechinus* also is more commonly met with in the higher portion of the Spergen than in the St. Louis proper.

St. Louis Limestone

Name. The St. Louis limestone was originally named from the city of St. Louis, Missouri, where the formation is finely developed. It has a wide distribution in the Mississippi and Ohio Valleys.

Distribution. In the Princeton Quadrangle the St. Louis limestone is limited in its distribution to the Crider, Princeton, McGowan and Saratoga rectangles, in four distinct fault blocks, all of which are in the region lying to the southwest of the much faulted northwest-southeast belt which crosses the quadrangle. There are two quite distinct areas of outcrop of the formation. The northernmost of these is an east-west belt about eight and one-half miles in length, varying from one to two miles wide, extending westward from the much faulted belt to the western edge of the quadrangle where the belt has its greatest width. The south edge of this belt is about one mile north of the center of the town of Princeton. This belt is divided diagonally, about three miles from its eastern extremity, by one of the longer faults of the region. The northern boundary of this belt is continuous, but its southern boundary is interrupted at the position of the diagonal fault by a small, wedge-shaped, down-dropped block of Pottsville sandstone.

The southernmost of the two St. Louis areas occurs in two large fault blocks, and has been exposed by reason of the erosion of the overlying Ste. Genevieve limestone by Eddy Creek and some of its tributaries, the most important of which is Dry Creek. The boundary of the formation in this area is exceedingly sinuous except along the south side of the Otter Creek fault (fault No. 88), where the St. Louis limestone is continuous for over eight miles from the western border of the quadrangle.

Lithologic characters. Good exposures of the St. Louis limestone are not common in the Princeton Quadrangle. Most of the area underlain by the formation is deeply covered with residual beds of red clay in which a great amount of chert is included. These residual clays are a conspicuous feature in the public roads, along the streams, and in gullies. The cherts are very little or not at all more abundant in the St. Louis limestone areas than in some portions of the region underlain by the Ste. Genevieve limestone, but the St. Louis cherts are somewhat different in character, and specimens of the fossil coral *Lithostrotion* are rather commonly met with in them. Much of the St. Louis chert is more dense and compact in texture, and less easily affected by weathering than a great deal of that in the Ste. Genevieve limestone, and many masses of it occur in more or less irregular chunks. No oolitic structure has been noticed in any of the cherts which are certainly of St. Louis age. Although there are distinct lithologic differences between the cherts of the two formations, in many places it is not possible to differentiate with certainty the St. Louis from the Ste. Genevieve by means of the cherts alone.

The limestone exposures of St. Louis age which have been met with exhibit some variations in character. There are several exposures in the eastern one-third of the fault block in the Princeton rectangle bounded by faults 44, 45, 39, and 33, along Flynn Creek and its main tributary in this region from the west. In these outcrops the limestone is gray in color, more or less dense and compact in texture, and some of it includes much chert. These outcrops are all in the higher portion of the formation. An outcrop of the lower beds is present in the southwestern part of the same fault block, a little less than a quarter of a mile north of fault No. 39, in the valley draining into the eastern end of the large crescent-shaped sink hole just northwest of the corporation limits of Princeton. The limestone is impure and dark in color, being interbedded with chert layers. The difference between the lower and higher beds of the formation is similar to that recognized in Hardin County, Illinois,[9] where the lower portion is made up of nearly black, impure limestone, the higher beds being much lighter and commonly gray in color.

More numerous outcrops of the formation are present in the southwestern portion of the quadrangle, more especially in the Saratoga rectangle, but even here the formation is largely covered with residuum. The limestone is gray to black in color in most places, compact to dense in texture, but in a few localities an oolitic bed has been observed in the lower portion of the formation as it is exposed. The cherts of the formation vary considerably at different horizons. In one zone near or below the middle of the formation there are numerous smooth, lenticular chert concretions with evenly convex sides and rather sharp periphery. These concretions vary in size from two or three inches to nearly a foot in diameter, and in places they occur in considerable numbers along stream channels in which this particular bed is exposed. Other chert masses are more or less irregular in shape. The more spherical chert concretions which are met with in the region are commonly from the lower portion of the Ste. Genevieve limestone, although similar cherts are rarely present in the St. Louis limestone in places. As in the formation north and northwest of Princeton, silicified specimens of *Lithostrotion proliferum* and *L. canadense* are met with commonly in the residual deposits.

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[9] Ill. State Geol. Surv., Bull. No. 41, p. 102 (1921).

Thickness. None of the exposures of the St. Louis limestone in the Princeton Quadrangle are of such a character that the full thickness of the formation can be measured. In the southwestern corner of the quadrangle at least 200 feet of strata referable to the formation have been uncovered by erosion in some of the tributaries of Eddy Creek. The whole of the formation has been penetrated in the deep well at Cedar Hill, but its exact limits cannot be determined, either above or below. There certainly is as much as 300 feet of strata in the well section which must be St. Louis limestone, and probably considerably more, perhaps more than 400 feet.

Stratigraphic relations. The stratigraphic relations of the St. Louis limestone in the Princeton Quadrangle are similar to those in other parts of the Ohio Valley. Sedimentation was continuous from the underlying Spergen or Salem, and also continued into the overlying Ste. Genevieve, with no stratigraphic breaks, consequently the formation is not set off by unconformities either below or above. Farther west, along the eastern flank of the Ozark region in southeastern Missouri, there is a distinct erosion unconformity between the St. Louis and the overlying Ste. Genevieve limestone, but the base of the formation passes by gradual transition into the underlying Spergen or Salem with no break. The unconformity at the top of the St. Louis in the region east of Ozarkia is undoubtedly due to one of the periodic uplifts of the Ozark dome which seems to have been raised repeatedly during the progress of Paleozoic time.

Ulrich has insisted that the boundary between the Ste. Genevieve and St. Louis limestones marks the lower limit of the Chester Series, and apparently infers that an important unconformity is generally present at this horizon. He has recognized the unconformity in Ste. Genevieve County, Missouri, and has attempted to show that in southeastern Tennessee the St. Louis limestone is in unconformable contact with both the Ste. Genevieve and the Spergen or Salem, and from these observations he has assumed that the St. Louis-Ste. Genevieve contact is unconformable across the entire intermediate area from the Appalachians to Ozarkia. He has published a photograph and sketch [10] of an exposure in an unused railroad cut five and one-half miles east of Jasper, Tennessee, in which he interprets certain partings in the rocks as the upper and lower boundaries of the St. Louis limestone, which he states is in unconformable contact both with the underlying Spergen and the overlying Ste. Genevieve, the greatest thickness of the bed considered as St. Louis limestone being less than ten feet. His only basis for identifying the so-called St. Louis limestone as such is the difference in lithologic character, which is not important, and the belief that the partings which he has observed are planes of unconformity. No paleontological evidence is presented, and none could be presented, to show that the strata so designated are Spergen, St. Louis and Ste. Genevieve.

In a recent examination by the writer of a series of sections including this stratigraphic interval in the Cumberland escarpment across Tennessee, it was found that the base of the Ste. Genevieve limestone is marked by a very persistent oolitic limestone bed which is especially characterized by numerous examples of the brachiopod *Rhipidomella dubia*. In most of the sections studied the St. Louis age of the strata beneath the *Rhipidomella* bed could be established by the presence of examples of the coral *Lithostrotion canadensis* or *L. proliferum*. At the *Rhipidomella dubia* horizon, or within a few feet of it the oolitic texture, so characteristic of the Ste. Genevieve limestone, is introduced, and the St. Louis limestone corals do not occur above this horizon. The persistence of this bed, three or four feet in thickness, with its characteristic fossils, makes it a most valuable key horizon, and if it is not the base of the Ste. Genevieve limestone it is close to that position. In the railroad cut east of Jasper, where Ulrich's photograph and sketch were taken, this characteristic *Rhipidomella* bed is well exhibited 50 feet beneath the layer which he has designated as

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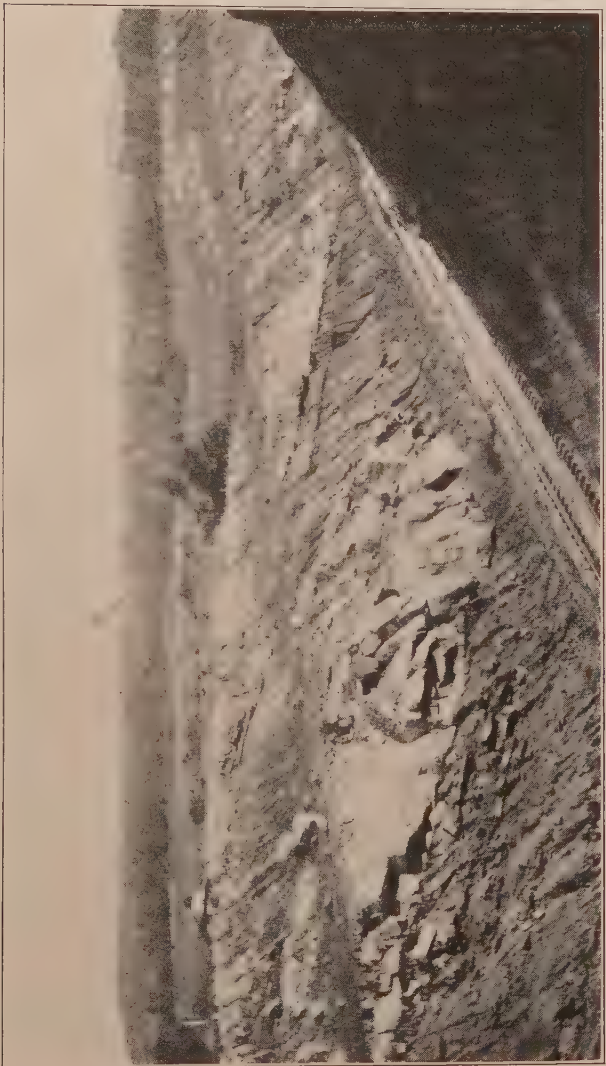
[10] Ky. Geol. Surv., Miss. Form. West. Ky., plates H-1 and H-2, pp. 101-102 (1917).



PANORAMA OF WALCHE'S CUT

The massive Tar Springs sandstone is excellently shown in Walche's Cut, Illinois Central Railroad, east of Scottsburg. At the left the shaly beds of the Glen Dean formation pass beneath the basal sandstone member of the Tar Springs. At the extereme right the Vienna Limestone is faulted against the Tar Springs. Characteristic Mississippian topography of the region.

the sole representative of the St. Louis. The upper part of the true St. Louis limestone is present in the section, being represented by beds of very cherty, compact limestone, similar in all respects to the St. Louis elsewhere in Tennessee, and there is no reason to believe that the formation is represented by any less thickness of strata here than elsewhere in the state. The so-called St. Louis of Ulrich is simply a local bed in the Ste. Genevieve, more cherty than the beds above and below it, and the stratigraphic value of the partings bounding the bed are vastly overestimated by him.

Paleontology. Good fossils are not numerous in the St. Louis limestone of the Princeton Quadrangle. Among the chert fragments along the road sides, in stream beds, and in gullies, silicified examples of the two species of the coral genus *Lithostrotion* are not infrequently met with. Less frequently some other fossils, for the most part imperfect brachiopods, are seen, but the fauna as a whole is rather meager, and no attempt has been made to make complete collections.

Correlation. The presence of the species of *Lithostrotion*, mentioned above, is sufficient to establish the correlation of the St. Louis limestone in the Princeton Quadrangle with this widespread formation of the Ohio and Mississippi Valleys, these corals being known from no other horizon.

STE. GENEVIEVE LIMESTONE

Name. The Ste. Genevieve limestone was first named many years ago from the exposures in the vicinity of Ste. Genevieve, Missouri. Ulrich first described the formation in Kentucky as the Princeton limestone,[11] but later he recognized that his formation was equivalent to the Ste. Genevieve and consequently adopted the older name first applied by Shumard in 1859 from exposures at Ste. Genevieve, Missouri.

Distribution. In the Princeton Quadrangle the Ste. Genevieve limestone underlies a larger proportion of the surface than any other single formation, but its entire distribution lies southwest of the conspicuous northwest-southeast belt of faulting. A number of smaller fault blocks in the northern portion of the Princeton rectangle are made up wholly or in part of Ste. Genevieve limestone. Two larger fault blocks in the Crider and Flat Rock rectangles include much more extensive areas of the formation, but all of these are separated from the most extensive area of the Ste. Genevieve limestone in the quadrangle, by the east-west belt of St. Louis limestone north of Princeton which has already been described. This larger area of the formation extends southward and westward from Princeton to the borders of the quadrangle, and is continuous in these directions except where erosion has cut through this limestone into the St. Louis in the southwestern portion of the area. This large area is crossed by three east-west faults between Princeton and the southern boundary of the quadrangle, which produce a series of offsets in the contacts between the Ste. Genevieve and the underlying and overlying formations. Along the southern boundary of the quadrangle the total length of outcrop of the Ste. Genevieve is over ten miles.

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[11] Crittenden Press, Dec., 1890; Bull. U. S. Geol. Surv., No. 213, p. 207 (1903).

Topographic Expression. Within the area occupied by the Ste. Genevieve limestone the land surface is characterized by gentle slopes, and a large portion of the area is tillable farming land. The area is particularly characterized by innumerable sink holes, varying in size from a few feet to as much as a mile in maximum dimension. These sinks dot the entire area, and through them the drainage is mostly underground, so that only a few valleys occupied by major streams or tributaries are present.

Subdivisions of the Ste. Genevieve. In Ulrich's[12] redefinition of the Ste. Genevieve limestone, he recognized three members, the Fredonia oolite below, followed by the Rosiclare sandstone, and the Ohara limestone at the top. In the original definition of the Ohara, the type locality being at Cedar Hill quarry, formerly known as Ohara Post Office, the Renault limestone was included as part of the member. Later studies have proven that only the lower part of the original Ohara is of Ste. Genevieve age, so that the subdivisions recognized in this report are Fredonia oolite, Rosiclare sandstone, and Lower Ohara limestone. No Upper Ohara limestone is recognized as such in the section, however, for those beds constitute the Renault limestone at the base of the Chester Series in the general section. By far the greater portion of the formation is included in the Fredonia member.

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[12] U. S. Geol. Surv., Prof. Paper No. 36, p. 39 (1905).

Lithologic characters. Some portions of the Ste. Genevieve limestone are not essentially different in lithologic character from some of the higher beds of the St. Louis limestone. Both formations are cherty, and great quantities of fragmentary chert in red clay are present in the residual accumulations from the limestones. There is some difference in character between the cherts from the two formations, but the differences are not sufficiently marked to make it possible in all cases to differentiate the formations from the cherts alone. One of the most characteristic lithological features of the Ste. Genevieve limestone, is the presence of beds of oolite. Only rarely has oolitic limestone been observed in the St. Louis, and in practice the field geologist draws his boundary line between the two formations below the last bed of oolite. The Ste. Genevieve limestone, however, is not oolitic throughout, and many beds, especially in the lower portion, are indistinguishable by themselves, from the St. Louis limestone. The oolitic beds become more and more conspicuous in passing upward in the formation, and the upper half of the Fredonia member is largely oolitic in character. On the whole the Ste. Genevieve is a whiter limestone than the St. Louis, the oolite beds especially being white in color. The oolitic texture is recognizable in some of the cherts of the Ste. Genevieve, this being one manner in which some of the Ste. Genevieve chert can be distinguished from that of the St. Louis limestone. In some portions of the formation the chert concretions are more or less globose in form, with smooth surfaces, such masses ranging up to ten inches or more in diameter. Similar, smooth, rounded cherts do occur in places in the St. Louis, but they are more common in the Ste. Genevieve, much of the St. Louis chert occurring as rather rough, more or less irregular masses. The higher, more oolitic beds of the formation are less cherty than the lower portion, some residual clays from the higher Fredonia being deep red in color and quite free from chert, but elsewhere the chert is present to the top of the Fredonia at least.

The Rosiclare sandstone member of the Ste. Genevieve is reddish-brown or yellowish-brown in color as it is commonly exhibited in its weathered condition, being fine grained and porous in character. Where it occurs in an unweathered condition, as shown in the Cedar Hill quarry, it is gray or greenish in color, and is more or less calcareous. In its original condition it is probable that the bed was everywhere a calcareous sandstone or arenaceous limestone, and that it only appears as a porous sandstone on the weathered outcrop. The Rosiclare varies from place to place in regard to its bedding, some portions of the sandstone being thinly bedded while other parts are more massive.

The Lower Ohara member of the Ste. Genevieve limestone resembles the Fredonia in its lithologic character. It includes oolitic limestone beds along with others which are more or less crystalline. A series of Lower Ohara beds out of connection with the Rosiclare sandstone or the overlying Renault limestone, would possess no lithologic character which would certainly differentiate them from a similar series of beds in the Fredonia.

Thickness. In the southernmost fault block in the Princeton quadrangle, the entire width of outcrop of the Ste Genevieve limestone is present from the St. Louis limestone below to the Renault above, this width being a little over ten miles. In this same area the basal contact of the formation can be followed continuously for several miles, and a drop of 80 feet in four miles can be observed. This would give, with a uniform dip, a total drop of 200 feet for the basal contact in the entire width of outcrop. The elevation of the lower and upper contacts of the formation in this area are essentially the same, so that a thickness of 200 feet may be accepted as the minimum for the formation. The deep well at Cedar Hill gives some check on the thickness of the formation, for the first samples saved, at a depth of 250 to 255 feet are clearly in the St. Louis limestone, and by adding 70 feet, which is the interval between the elevation at the mouth of the well and the summit of the formation in the Cedar Hill quarry, a maximum limit of 320 feet is established. How much less than this the actual thickness of the formation really is, has not been determined. Observations in Hardin County, Illinois, have led to an estimate of 300 feet as the maximum thickness of the Ste. Genevieve, and a similar thickness may perhaps be expected about Princeton.

Of the entire thickness of the Ste. Genevieve limestone the Fredonia constitutes much the larger part. The Rosiclare sandstone member is thin, varying from two feet to twenty. The Lower Ohara varies somewhat because of the erosion interval which succeeded it, its maximum thickness being perhaps 50 feet.

Stratigraphic relations. The Ste. Genevieve limestone rests with entire conformity upon the St. Louis. Because of the deep covering of residual materials, composed of quantities of chert imbedded in red clay, the actual contact of the two formations has nowhere been observed in the Princeton quadrangle, and the mapping of this boundary is most difficult. Nowhere in the section is there any sharp demarkation of the two formations, but in general the St. Louis is made up of more dense and compact limestone beds, although there are just as dense and compact beds in the Ste. Genevieve as any of those in the St. Louis. In the Ste. Genevieve limestone oolitic limestone beds are commonly present, but not all of the formation is of that character, and in a few localities oolitic beds have been observed in undoubted St. Louis limestone. The St. Louis-Ste. Genevieve limestone represents one continuous geologic epoch during which the conditions of sedimentation were gradually changing, and the lower St. Louis limestone in western Kentucky is distinctly different from the upper Ste. Genevieve. The upper St. Louis, however, and the lower Ste. Genevieve are much alike and there are some 40 to 50 feet of limestones which might be placed in either formation so far as the lithologic characters are concerned.

The fossils furnish some assistance in separating the two formations, although in neither of them are the fossils either abundant or well preserved except very locally. The coral genus *Lithostrotion*, represented by two species, *L. proliferum* and *L. canadense*, is one of the most common fossils of the St. Louis limestone, and neither of these species have been observed in the Ste. Genevieve limestone. These corals are commonly silicified and occur in many places with the residual cherts, and

UPPER PORTION TAR SPRINGS SANDSTONE.

Shale and impure coal bed in Tar Springs Sandstone, Walche's Cut, Illinois Central Railroad, east of Scottsburg.

their presence in such situations has been taken as evidence of the presence of the St. Louis limestone.

The fossil form which is the best indicator for the Ste. Genevieve limestone is the crinoid *Platycrinus penicillus.* This species is represented most commonly by the separate stem segments which have the elliptical form characteristic of the genus, and are ornamented by a series of projecting spines about the margin. The bases of the crinoid are also common in places, and may be easily recognized by the three ridges radiating from the stem facet. This crinoid is not restricted to the Ste. Genevieve, being also present in the St. Louis, but it is much more abundant in the higher formation.

In field practice, where the limestone outcrops are scarce or wanting, careful search has been made for loose specimens of silicified *Lithostrotion* in gullies and along roads, and the highest occurrence of such specimens is assumed to be somewhat below the contact between the two formations.

In general the red clay residuum of the Ste. Genevieve, especially the Fredonia limestone, is much deeper red than that of the St. Louis, and in the higher part of the formation, in many localities, it is quite free from chert. In the basal part of the Fredonia, however, overlying the last of the *Lithostrotion* bearing cherts, there is a characteristic, highly cherty residuum with deep red Fredonia color, and including great numbers of smooth, sub-globular cherts varying from two or three inches to ten or twelve inches in diameter. In the absence of limestone outcrops this type of residuum has been mapped as basal Ste. Genevieve limestone, for it distinctly overlies the *Lithostrotion* bearing beds. Somewhat similar globular cherts do occur in places in the St. Louis limestone, but never in such abundance.

At its upper boundary the Ste. Genevieve is succeeded by the Renault limestone, from which it is separated by a distinct unconformity, which will be discussed in connection with the description of the higher formation.

Paleontology. Fragmentary remains of fossils are everywhere present in the Ste. Genevieve limestone, but well preserved fossils are not commonly met with. The best fossil material has been collected from certain shaly beds near the top of the Fredonia member. A very characteristic feature of the weathered surfaces of this Ste. Genevieve limestone is the presence of the elliptical stem plates of the crinoid *Platycrinus penicillus*, with their characteristic marginal spines. Upon some beds these Platycrinus plates are wanting, but if any considerable exposure is available, they can be found in almost any locality. The same sort of plates are also present, but less commonly, in the St. Louis limestone, but wherever such plates are really abundant the limestone is quite certainly Ste. Genevieve. The plates are present in both the Fredonia and Lower Ohara members of the formation. They have nowhere been observed above the Ste. Genevieve.

Locally in the upper part of the Fredonia member, there are numerous masses of a colonial coral, *Lithostrotion harmodites*, which is known in no other formation. The coral masses attain dimensions of a foot or more across, and have been observed very commonly along the public road running northeast from Bethlehem School, one mile north of Crider.

A characteristic Ste. Genevieve limestone fauna, from the upper part of the Fredonia member, one mile northeast of Crider, contains the following species:

Lithostrotion harmodites (M.-E. & H.)
Michelinia subramosa Ulrich.
Unidentified coral.
Pentremites princetonensis Ulrich.
P. pulchellus Ulrich.
Platycrinus penicillus M. & W.
Bryozoan.
Productus sp. cf. *P. parvus.*
Pustula genevievensis (Weller).
Rhipidomella dubia (Hall).
Pugnoides ottumwa (White).
Girtyella indianensis (Girty).
Spiriferina sp.
Spirifer pellaensis Weller.
Reticularia setigera (Hall).
Eumetria verneuilana (Hall).
Cliothyridina sublamellosa (Hall.)
Composita trinuclea (Hall).
Aviculopecten sp.
Platyceras sp.

A fauna from a similar horizon, .8 mile north of the last mentioned locality and one and one-half miles northeast of Crider, has furnished the following species:

Lithostrotion harmodites (M.-E. & H.)
Cystelasma sp.?
Platycrinus penicillus M. & W.
Dizygocrinus persculptus Ulrich.
Pentremites princetonensis Ulrich.
P. pulchellus Ulrich.
Productus ovoides (Hall).
Productus sp.
Rhipidomella dubia (Hall).
Girtyella indianensis (Girty).
Pugnoides ottumwa (White).
Spiriferina sp.
Spirifer sp.
Eumetria verneuiliana (Hall).
Cliothyridina sublamellosa (Hall).
Composita trinuclea (Hall).
Platyceras sp.

CHAPTER IV.

STRATIGRAPHIC GEOLOGY, CHESTER SERIES

Every one of the formational units which have been recognized and described in the Chester Series of the Ohio Valley has been identified in the Princeton Quadrangle. The best locality for the exhibition of the entire succession of Chester formations is in Walche's cut on the new line of the Illinois Central railroad a little less than two miles northeast of Scottsburg. A number of faults cross the cut so that portions of some of the formations are not exposed by reason of the dislocation of beds which has taken place, but every one of the Chester formations except those above the Palestine sandstone is exposed to some extent, and the higher formations are present in the cuts between the end of Walche's cut and Claxton station. The older formations of the series are exhibited in the western part of the cut, the younger ones to the east. No excavation could have been made anywhere within the Quadrangle to exhibit the Chester succession more completely than is done in this railroad cut.

RENAULT LIMESTONE

Name. The lowest formation of the Chester Series in the Ohio Valley is the Renault. In the Mississippi River section the Aux Vases sandstone separates the Renault from the underlying Ste. Genevieve limestone, but this sandstone is represented by a part at least of the time interval of the unconformity between the Ste. Genevieve and the Renault. In the Princeton Quadrangle and throughout the Ohio Valley the Renault is for the most part limestone with some shale partings, but in the Mississippi Valley, where the formation was first named from Renault Township, Monroe County, Illinois, it contains sandstone members and also some extensive shale members.

Distribution. The distribution of the Renault limestone in the Princeton Quadrangle is along a belt from four to five miles or less in width, extending from the southeastern corner of the quadrangle to the western border about three miles from the northwestern corner. The actual outcrop of the formation within this belt is rarely more than a fraction of a mile in width. The outcrop is extremely sinuous and irregular in its distribution within the broader belt mentioned, and lacks continuity because of the fault dislocations within the belt. Throughout much of its extent the Renault outcrop occupies rather steeply sloping hillsides, which are capped by the Bethel sandstone, and at whose base the Ste. Genevieve limestone spreads away in a comparatively level surface. The distribution of the formation in detail is shown upon the accompanying map.

Lithologic characters. The Renault limestone is somewhat variable in character, although it is rather persistently gray in color, some parts of it being nearly white, and some yellow or buff beds are locally present. The weathered surfaces are commonly smooth and rounded where they are well exposed. The texture varies from dense and compact to more or less crystalline, the yellow beds, where present, being somewhat earthy. Most of the beds are hard, breaking with a more or less splintery fracture. The limestone layers are commonly separated by shaly partings, and at some horizons, especially towards the top of the formation, there are beds of calcareous shales two or three feet thick in places. The basal, more shaly beds which are so well developed in the Golconda Quadrangle in Livingston County, and the adjacent Hardin County, Illinois, and which have been called the Shelterville member of the formation,[1] are not well exhibited in the Princeton Quadrangle. Either this part of the formation is not present in the area, or as is more likely, it is represented by some of the limestone beds.

At the base of the Renault, just above its contact with the underlying Ste. Genevieve limestone, there is very persistently present a conglomerate or brecciated layer about one foot, more or less, in thickness. This layer has been observed in numerous localities in the quadrangle, and doubtless it is present throughout the area. In those places where the bed has not been observed it probably is present, but is now covered with superficial material. The fragments included in this conglomerate or breccia are all limestone, and are commonly somewhat different in color and somewhat more dense than the gray matrix in

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[1] Ill. State Geol. Surv., Bull. No. 41, p. 133; also Jour. Geol., Vol. XXVIII, p. 290 (1920).

DETAIL OF RENAULT LIMESTONE.

These beds occupy a nearly horizontal position in Walche's Cut, Illinois Central Railroad east of Scottsburg.

which they are inclosed. They are angular to rounded in outline and vary in size from a small fraction of an inch to an inch or more across. This layer is undoubtedly associated with the unconformity which exists between the Renault and the underlying Ste. Genevieve limestone.

Thickness. The Renault formation varies somewhat in thickness within the quadrangle, although this variation is not excessive. Its usual thickness is about 80 feet, but in a few places it seems to be less than this, perhaps as little as 60 feet, and elsewhere it seems to exceed the average thickness, and may be nearly 100 feet thick.

Stratigraphic relations. The unconformity at the base of the Renault is the most important stratigraphic break in the whole Mississippian System in the Ohio and Mississippi Valleys, being the boundary line between the Iowa and Chester Series. The withdrawal of the sea from the interior of the continent was more complete at this time than at any other, and with the readvance of the sea into the Chester embayment, the new faunas of the Chester Series were introduced. Aside from the notable faunal change in passing from the Ste. Genevieve into the Renault limestone, the presence of the conglomerate or breccia bed at the base of the Renault is good physical evidence of the unconformity, and where the actual contact between the two formations can be seen there are some irregularities in the surface upon which the younger sediments were laid down.

The contact between the Renault and the overlying Bethel sandstone has nowhere been observed in the Princeton Quadrangle. There is an abrupt change, however, from the limestone to the sandstone, and where the contact has been seen in Hardin County, Illinois,[2] there is no doubt of an unconformable relation, and the same condition doubtless exists throughout this portion of Kentucky.

Paleontology. The Renault limestone is characteristically the zone of the crinoid genus *Talarocrinus*. A number of different species of the genus have been described from the faunas of this formation in Kentucky and southern Illinois, but the genus is entirely unknown in the Ste. Genevieve limestone faunas, and it is rare in the next higher limestone formation, the Paint Creek, being unknown from any other horizon in the Chester Series. This *Talarocrinus* faunal zone is a most characteristic feature of the Renault limestone from Monroe County, Illinois across the whole of southern Illinois, into Kentucky. Among the other forms associated with *Talarocrinus* may be mentioned the bryozoan *Cystodictya labiosa*. The genus *Cysto-*

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[2] Ill. State Geol. Surv., Bull. No. 41, pp. 146-147.

dictya has not been observed in any Ste. Genevieve limestone fauna. The species *C. labiosa* occurs in many localities in the Renault, but it does not become really abundant until the Paint Creek. Higher than the Paint Creek neither the species nor the genus are known, so that in association with other things this bryozoan is useful in some places in determining the horizon. Another feature of the Renault fauna is the presence for the first time of the pyriform species of Pentremites. A few species pass over from the Ste. Genevieve into the Renault, but all of them are long range types that are either present or are represented by closely allied species in faunas still older than the Ste. Genevieve. The most characteristic elements in the Renault faunas are the characteristically Chester forms which are introduced for the first time. The most prolific fauna of the Renault in western Kentucky is that of the basal, Shetlerville member of the formation, which is not well developed in the Princeton Quadrangle. The hard limestone beds of the formation are not of a character to permit the preservation of the fossils in good condition for collecting, but there are some shaly beds which have furnished small but very characteristic faunas.

At the Cedar Hill quarry fossils have been collected from three different beds in the Renault limestone, one near the base, second from a shale bed near the middle, and third from a limestone bed at the top of the formation. In the following list all of the species which have been recognized from the three beds are recorded, their occurrence in the three different beds being indicated in the three columns, 1, 2, and 3, numbered from the lower to the higher.

Renault Faunas from Cedar Hill Quarry

	1	2	3
Triplophyllum spinulosum (M.-E. & H.)	*	*	?
Talarocrinus buttsi Ulrich	*	----	----
Talarocrinus trijugis M. & G.	----	----	*
Pentremites godoni DeFrance	----	*	----
Pentremites buttsi Ulrich	----	....	*
Pentremites sp.	*	----	----
Corynotrypa sp.	----	*	----
Fistulipora excelens Ulrich	*	*	----

Renault Faunas from Cedar Hill Quarry—Continued.

	1	2	3
Eridopora sp.		*	
Batostomella spinulosa Ulrich		*	
Fenestella tenax Ulrich	*	*	
Fenestella serrulata Ulrich		*	
Fenestella cestriensis Ulrich	*	*	
Polypora cestriensis Ulrich	*		
Polypora sp.			*
Lyropora quincuncialis Ulrich			*
Lyropora sp.		*	
Septopora subquadrans Ulrich		*	
Cystodictya labiosa Weller	*	*	
Glyptopora punctipora Ulrich	*		
Phractopora sp.	*	*	
Orthotetes kaskaskiensis (McChesney)	*	*	*
Productus ovatus Hall	*	*	*
Productus inflatus McChesney			*
Diaphragmus elegans (N. & P.)	*	*	*
Girtyella indianensis (Girty)		*	*
Girtyella brevilobatus (Swallow)	*		
Spiriferina transversa (McChesney)	*	*	*
Spiriferina spinosa (N. & P.)			*
Spirifer pellaensis Weller	*		*
Spirifer increbescens var. *transversa* Hall		*	
Spirifer leidyi N. & P.	*		
Eumetria vera (Hall)	*	*	*
Cleiothyridina sublamellosa (Hall)	*	*	*
Composita trinuclea (Hall)	*	*	*
Schizodus sp.			*
Orthonychia cf. *chesterensis* M. & W.	*		
Euomphalus cf. *planidorsatus* M. & W.	*		
Phillipsia sp.		*	*
Cladodus sp.			*

Very good collections have been made from the higher part of the Renault limestone at two localities northeast of Otter Pond, the first from about three-fourths of a mile from the railroad station and the other about one and one-fourth miles from the same point. Both collections are from shaly beds, and it is not improbable that the horizon is the same at the two localities. A combined list of the species in these collections is given below, the two occurrences being indicated in the columns 1 and 2:

Renault Faunas Northeast of Otter Pond

	1	2
Triplophyllum spinulosum (M.-E. & H.)	*	*
Talarocrinus sp.	*	*
Crinoid plates and stems	*	*
Pentremites princetonensis Ulrich	*	*
Echinoid spines and plates	*	....
Fistulipora excelens Ulrich	----	*
Eridopora punctipora Ulrich	*	....
Batostomella nitidula Ulrich	*	....
Batostomella sp.	*	....
Stenopora tuberculata Prout	*	....
Anisotrypa sp.	*	....
Fenestella serratula Ulrich	*	....
Fenestella tenax Ulrich	*	....
Polypora sp.	*	....
Lyropora sp.	*	....
Rhombopora tuberculata Ulrich	*	....
Cystodictya labiosa Weller	*	....
Crania sp.	*	....
Orthotetes kaskaskiensis (McChesney)	*	*
Productus ovatus Hall	*	*
Diaphragmus elegans (N. & P.)	*	*
Dielasma illinoisensis Weller	*	....
Girtyella indianensis (Girty)	*	*
Girtyella brevilobata (Swallow)	*	*
Spiriferina transversa (McChesney)	*	*
Spirifer increbescens var. *transversa* Hall	*	....
Spirifer sp.	*	*
Eumetria vera (Hall)	*	*
Cliothyridina sublamellosa (Hall)	*	*
Composita trinuclea (Hall)	*	*
Platyceras sp.	*	*
Bellerophon sp.	*	*
Straparollus sp.	*	*
Allorisma clavata (McChesney)	----	*
Phillipsia sp.	*	*

Along the lower slopes of the hillside one-fourth mile west of McGowan Station, some silicified Renault fossils occur in the red residual clays, and from this locality the following species have been identified:

Renault Fossils from Near McGowan

Triplophyllum spinulosum (M.-E. & H.)
Talarocrinus trijugis M. & G.
Pentremites princetonensis Ulrich.
Pentremites buttsi Ulrich.
Spiriferina sp.
Cleiothyridina sublamellosa (Hall).
Composita trinuclea (Hall).

From some localities in the Renault limestone of the Princeton Quadrangle, a fauna somewhat different from those recorded above, has been collected. It is a fauna which seems to be associated with thin shaly partings between more massive limestone beds, which are really rather shaly limestone layers. From such a bed, one mile north of Princeton, the following species have been collected:

Renault Fossils from North of Princeton

Triplophyllum spinulosum (M.-E. & H.)
Cystodictya labiosa Weller.
Orthotetes kaskaskiensis (McChesney).
Productus ovatus Hall.
Diaphragmus elegans (N. & P.)
Spiriferina transversa (McChesney).
Spirifer breckenridgensis Weller.
Spirifer cf. *pellaensis* Weller.
Cliothyridina sublamellosa (Hall).
Composita trinuclea (Hall).
Platyceras sp.

In this fauna the large brachiopods, *Orthotetes kaskaskiensis* and *Productus ovatus* are by far the most numerous species, the remaining forms being represented by a very limited number of individuals.

Correlation. The question of the correlation of the Renault limestone has been fully discussed in the report on Hardin County, Illinois.[3] Ulrich included the formation in his Ohara member of the Ste. Genevieve limestone, and seemingly because of its Chester fauna he transferred the whole of his Ste. Genevieve limestone to the Chester Group. Extensive faunal studies of all of these beds, and the detailed mapping of the formations entirely across southern Illinois and into western Kentucky, have established the fact that the inclusion of the Ste. Genevieve limestone proper in the Chester Series is entirely unwarranted. The detailed field studies continue to pile up the evidence for the exact correlation of the "Upper Ohara" of Ulrich's section with the Renault limestone of the Mississippi Valley section. The bed has now been actually traced and mapped in detail from Caldwell County, Kentucky, to and across Union County, Illinois.

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[3] Ill. State Geol. Surv., Bull. No. 41, pp. 150-159 (1921).

It has been shown elsewhere that the Renault ("Upper Ohara") limestone fauna, including that of the Shetlerville member, from Hardin County, Illinois, is essentially the fauna of the typical Renault of Monroe County, Illinois, with the exception of three species which have been described as new and which are known only from the Shetlerville. It has also been shown that the diagnostic fossils of the Ste. Genevieve limestone. *Platycrinus penicillus* and *Pugnoides ottumwa* are entirely unknown from the Renault ("Upper Ohara") or any other Chester fauna. The species which are common to both the "Upper Ohara" and the Ste. Genevieve are in nearly every case long range forms which either are present in pre-Ste. Genevieve beds or are represented there by closely allied forms. The observations which have been made in Kentucky during the past two field seasons have confirmed the earlier conclusions in regard to the relationships of the faunas, in every respect. The correlation of the so-called "Upper Ohara" with the typical Renault is established beyond question, and the extension of the name Renault into southern Illinois and Kentucky is fully justified.

BETHEL SANDSTONE

Name. In his description of the Mississippian section in western Kentucky, Ulrich[4] described a sandstone formation resting upon his Ohara member of the Ste. Genevieve limestone, which he identified as the Cypress sandstone of Engelmann, originally described from southern Illinois. In 1915 the writer established the fact that the Cypress of Ulrich was not the original Cypress of Engelmann, but a lower member of the

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[4] Prof. Paper, U. S. Geol. Surv., No. 36, p. 53 (1905).

Chester Series. A statement to this effect was made in December, 1915,[5] and the correction was accepted by Ulrich. In 1917 Butts proposed the name Bethel sandstone[6] for this formation which Ulrich had erroneously called Cypress, a name which has been adopted and used by all later workers in this field.

Distribution. The distribution of the Bethel sandstone in the Princeton Quadrangle follows closely that of the underlying Renault limestone. The usual dip of all the strata throughout the area is to the northeast, and in general this sandstone underlies a cuesta slope, much interrupted and broken by faults, sloping northwestwardly from the summit of the bluff-like exposures of the Renault. If the earth's crust in this quadrangle had never suffered the disturbances which are evidenced by the complex faulting, the Bethel sandstone would have constituted a continuous belt from one to two miles wide, extending from the southeastern corner of the quadrangle to the western border, about four miles south of the northwest corner. As it exists today the outcrop of the formation is restricted for the most part to this belt, just southwest of the major northwest-southeast lines of faulting, but it is offset to the east or to the west a number of times by the east-west faults which cross the quadrangle, so that the total width of the belt in which the outcrop is included is considerably greater than it would have been otherwise. The pattern of the outcrop is made very irregular through this belt by reason of the effects of stream erosion.

Lithologic characters. As it is exposed in surface outcrop in the Princeton Quadrangle, the Bethel sandstone is commonly light brown in color, moderately fine grained in texture, and more or less friable in character. Much of the formation is massively bedded with much cross bedding, but locally it is thinly and evenly bedded. If the sandstone were encountered under cover, as in well drilling, the sand might be expected to be less oxidised and somewhat lighter in color. It is probably the coarsest in texture of any of the sandstone formations of the Chester Series in this area, it is as massive as any of the others, although some of the beds in the Tar Springs and also the Palestine sandstones are as massive.

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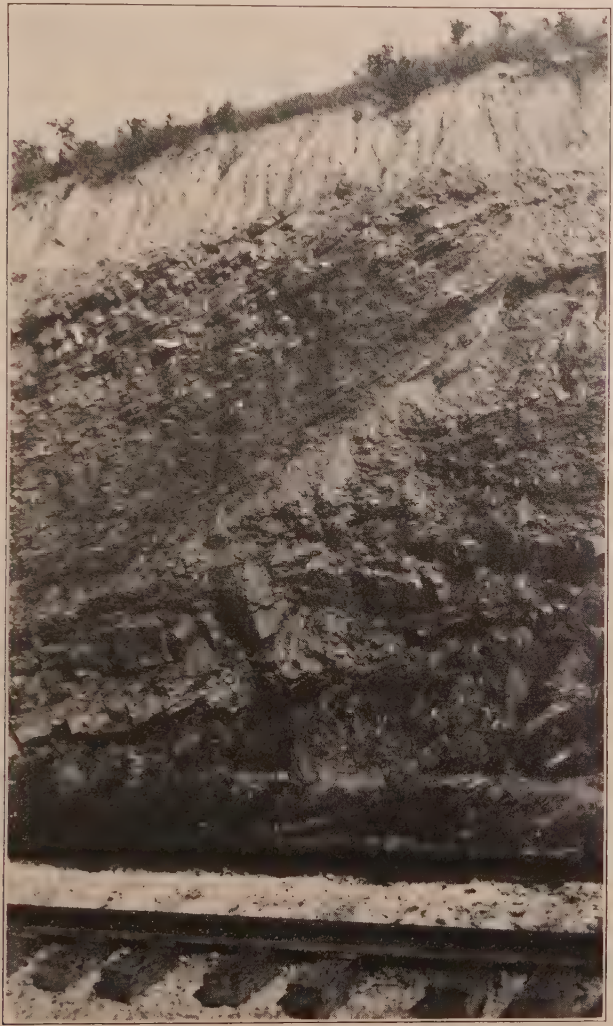
[5] Paper read before Geol. Soc. Amer., but not published.
[6] Ky. Geol. Surv., Miss. Form. West. Ky., p. 63 (1917).



A THRUST FAULT IN THE BETHEL SANDSTONE.

The small fault may be seen in Walche's Cut, Illinois Central Railroad, east of Scottsburg.

Thickness. The usual thickness of the Bethel sandstone about Princeton is about 40 feet, but in one locality at least, two and one-half miles east of the town, there is a thickness of only 25 feet.

Stratigraphic relations. Presumably the Bethel sandstone lies unconformably upon the underlying Renault limestone. The actual contact between the two formations is best exhibited in the Quadrangle, in Walche's cut on the new line of the Illinois Central Railroad, northeast of Scottsburg. The two formations are exposed west of the bridge crossing the cut, the sandstone at this locality being more thinly bedded than usual. Throughout a part of the section the sandstone apparently rests upon a massive, cherty limestone member of the Renault, but elsewhere there is a layer of variegated clay shale between it and the same cherty limestone bed, a condition which suggests the removal, in places, of the shale before the sandstone was deposited. In Hardin County, Illinois, the contact between these two formations is well exhibited in the Ohio River bluffs[7] and clearly shows the unconformity between them, and it is not unlikely that this unconformity continues to the Princeton Quadrangle.

The contact between the Bethel and the overlying Paint Creek formation has not been observed. There seems to be an abrupt change from the sandstone into the overlying limestones and shales, which suggests a condition of unconformity, and there is some evidence of unconformable relations at this horizon in Hardin County, Illinois. However, with the present information available it is not possible either to affirm or deny such an unconformity in the Princeton Quadrangle.

Paleontology. No fossils of importance have been detected in the Bethel sandstone in the Princeton Quadrangle, although in places there are fragments of undeterminable plant remains such as are found in the formation throughout its extent in Kentucky and Illinois.

Correlation. The Bethel sandstone has been traced and mapped in detail from the Princeton Quadrangle in Kentucky, to near Anna, Union County, Illinois. The formation thins materially towards the western portion of its outcrop in Illinois, and in at least one, and perhaps in other localities of small extent, it is absent altogether, permitting the Paint Creek to rest upon the Renault. The continuity of the bed throughout the whole distance, however, is unquestioned. The formation is said by Butts to continue eastward from the Princeton Quadrangle to near Fairview, close to the line between Christian and Todd Counties, Kentucky, but, according to the same author, it has not been observed farther east.[8]

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[7] Ill. State Geol. Surv., Bull. No. 41, pp. 146-147 (1921).

In the Mississippi River sections of the Chester Series, the position of the Bethel sandstone is occupied by the Yankeetown formation, a thin, siliceous bed which is in part chert, and locally a quartzite.

In Breckenridge County, Kentucky, Butts has described the Sample sandstone, assigning it to a position supposed to be higher in the Chester Series than that occupied by the Bethel.[9] There seems to be no doubt, however, that the Sample is the exact equivalent of the Bethel, and consequently the name Sample should be abandoned. The relationship of the Bethel and Sample sandstones will be discussed more fully on a later page, in connection with the consideration of the Paint Creek formation, and the so-called Gasper limestone of Butts.

Paint Creek Limestone

Name. This formation was originally described from Monroe and Randolph Counties, Illinois, the name being taken from a stream in southern Monroe County. The formation has been recognized and mapped in detail across these Mississippi River counties in Illinois and southward across the Mississippi River into Perry County, Missouri, also across the southern counties of Illinois from Union to Hardin, and across the Ohio River into Livingston, Crittenden and Caldwell Counties, Kentucky.

When Ulrich first described the Chester section of western Kentucky, he defined the Tribune limestone as a formation with oolitic beds, overlying the Bethel sandstone, which he at that time called the Cypress sandstone. The formation was named from outcrops at Tribune, six miles east of Marion, which have been shown by the writer to belong far up in the Chester section, really being a part of the Menard limestone.[10] Another of the original Tribune localities specified by Ulrich is the limestone outcrop at the mouth of the Fairview Mine at Rosiclare, Illinois, and this limestone has been shown by the writer to be the Renault.[11] Still another of the specified localities for the Tribune limestone, designated by Ulrich is in Livingston County, Kentucky, east of Joy. Detailed mapping of this region has shown that no limestone of any sort is present at the locality indicated, and that it is situated in the midst of an unbroken area of Cypress sandstone.

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[8] Ky. Geol. Surv., Miss. Form. W. Ky., p. 63 (1917).
[9] Geol. Surv. Ky., Miss. Form. W. Ky, p 70 (1917)
[10] Paper read at the Washington Meeting of Geol. Soc. Amer., but not published (1915).

In his later contributions Ulrich[12] has indicated that what he really intended to designate as Tribune is certain limestone exposures between Princeton and Hopkinsville, at about the line between Caldwell and Christian Counties, which are just a little east of the Princeton Quadrangle, and beds at another exposure east of Scottsburg which are in the Princeton Quadrangle. The limestones at both of these two localities are the Paint Creek of this report.

An attempt has been made by Butts to eliminate the confusion introduced by Ulrich by his naming of a formation defined as overlying the Bethel (Cypress of Ulrich) sandstone, from outcrops at Tribune which occupy a very different stratigraphic position, by the proposal of the name Gasper[13] as a substitute for Tribune, a substitute accepted by Ulrich. As used by Butts and Ulrich the Gasper includes not only the "Tribune" east of Princeton, which is the exact equivalent of the Paint Creek, but also beds which are clearly the exact equivalents of the Renault, the Sample sandstone member of the Gasper in Breckenridge County, being really nothing else than the more eastern manifestation of the Bethel sandstone. The introduction of the name Gasper, therefore, has not clarified the situation in the least. The Paint Creek of southern Illinois is clearly the exact equivalent of the beds in western Kentucky to which Ulrich intended to apply the name Tribune, and even if the Gasper were the exact equivalent of Ulrich's earlier name it would be ruled out by the prior name Paint Creek.

Distribution. In the Princeton Quadrangle the surface exposures of the Paint Creek formation are confined in general, to the same northwest-southeast belt in which the Renault and

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[11] Ill. State Geol. Surv., Bull. No. 41, p. 155 (1921).
[12] Ky. Geol. Surv., Miss. Form. W. Ky., pp. 91-92 (1917)
[13] Ky. Geol. Surv., Miss. Form. W. Ky., p. 64 (1917).

Bethel are found. In his original description of the Tribune limestone, which properly interpreted, as already pointed out, is the exact equivalent of the Paint Creek, Ulrich says[14] "The Tribune limestone rarely comes to the surface in the region under discussion. Indeed it has been certainly recognized in only six localities in the district, and at only five points in the area covered by the map accompanying this report." Of the six localities named by Ulrich that at Tribune, Kentucky, is Menard limestone, that east of Joy is in the midst of the Cypress sandstone, and that at the Fairview mine at Rosiclare is Renault limestone. The locality at Lamb's cut on the old line of the Illinois Central Railroad is the only one of the original localities specified by Ulrich which lies within the limits of the Princeton Quadrangle, and it does occupy the true position assigned to the formation. This Lamb's cut outcrop, however, is really one of the less important of the Paint Creek outcrops in the Quadrangle, and there are many other excellent and abundantly fossiliferous exposures of the formation which were mapped as Birdsville by Ulrich. From this situation, therefore, it will be seen that Ulrich not only misidentified much of his so-called Tribune, but also failed to recognize a great deal of limestone which he should properly have placed in the formation.

The greater portion of the Paint Creek in the quadrangle lies to the southeast of Princeton. The areas of outcrop are somewhat scattered and discontinuous by reason of the extreme faulting, but the distribution is shown upon the accompanying map. One area of considerable extent lies northwest of Princeton, in the fault block bounded by faults 11, 28, 29, and 30.

Lithologic characters. The Paint Creek is in the main a limestone formation with interbedded shale layers of varying thickness. Everywhere in the quadrangle, where the formation is exposed, the outcrop is more or less covered with talus or residuum, so that the exact succession of beds in the formation cannot be determined. There seems to be a considerable number of limestone ledges with shale partings in the lower part of the formation, then a series of beds that are more shaly, with numerous fossils, and above this a third division which again is made up of more or less massive limestone ledges interbedded with shale layers. Some beds in the lower part of the formation are oolitic in texture and carry a fauna including many small molluscs, and some oolitic beds are present locally in other portions of the formation, but the formation, as a whole, is not nearly so much of an oolitic limestone as the reader of Ulrich's original description of the Tribune limestone would be led to believe. Some of the limestone beds of the formation, especially some of those in the higher portion, are hard and dense, weathering with smooth surfaces, and closely resemble in their outcrop some of the Renault exposures, but in the main the Paint Creek limestones are more crystalline than the Renault, and crumble somewhat under conditions of weathering, so that the weathered surfaces are rougher and give a better opportunity for the growth of lichens and mosses, which are most generally absent from the Renault exposures. The greater amount of shale in the Paint Creek also produces more slumping and more talus covering than is present over much of the Renault outcrop.

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[14] Prof. Paper, U. S. Geol. Surv., No. 36, p. 59 (1905).

As the Paint Creek is developed in Livingston County, Kentucky, and across the Ohio River in the southern counties of Illinois, it is very largely a shale formation, much of the shale being black or greenish in color and very fissile in character. Some of the shales in the middle portion of the Paint Creek in the Princeton Quadrangle are entirely like those of the section near the Ohio River, a good exhibition of such a shale being along the public highway between Cedar Hill and Scottsburg, just south of fault No. 70. The westernmost exposures of the Paint Creek in the quadrangle are about one and one-fourth miles from the western border, a little southeast of Good Spring School, and the exposure at this locality is composed of about as much limestone as is present elsewhere in the quadrangle, so that the transition from the more calcareous to the nearly complete shale facies of the formation must take place across Crittenden County for the most part.

In the upper part of the Paint Creek formation there is locally at least, a thin, more or less calcareous sandstone layer, followed by a few feet of more calcareous beds, beneath the continuous sandstone of the overlying Cypress formation. Some question might be raised as to whether the sandstone should be included in the Paint Creek, or whether the limestone should be considered as a part of the Cypress, but it seems best to draw the line between the two formations above the highest limestone. This situation is best exhibited near Scottsburg, a little southeast of the village.

Thickness. The full thickness of the Paint Creek is not exposed continuously anywhere in the quadrangle, in such a manner as to permit its measurement, bed by bed, but at a number of places the interval between the underlying Bethel and the overlying Cypress sandstones can be rather closely determined, giving a thickness of essentially 100 feet for the Paint Creek. There is probably very little variation from this thickness anywhere in the Quadrangle.

Stratigraphic relations. It cannot be certainly established whether the Paint Creek rests unconformably upon the Bethel sandstone or not. At no locality in the quadrangle has the actual contact between the two formations been observed. In southern Illinois there is some evidence suggesting the presence of an unconformity at this horizon, but the beds might be unconformable there and still be perfectly conformable at Princeton, Kentucky. The presence of a thin sandstone bed in the upper part of the Paint Creek, followed by a recurrent bed of limestone, suggests that there was some alternation of conditions in the region at the time of transition from the Paint Creek to the overlying Cypress, and that the stratigraphic succession is really uninterrupted.

Paleontology. The Paint Creek is perhaps the most fossiliferous formation of the entire Chester Series in the Princeton Quadrangle, at least the fossils are most favorably preserved for purposes of collecting. Most of the limestone beds of the formation are only sparingly fossiliferous, and the fossils present are indifferently preserved. Some oolitic beds, locally present, near the base of the formation, do contain many fossils which constitute a rather varied fauna containing numerous small molluscs among other things. The most fossiliferous portion of the formation is some of the calcareous shale beds with thin limestone layers, in the middle portion of the formation. Upon some glade-like exposures of these beds great numbers of very perfectly preserved fossils can be collected, belonging to many species of brachiopods, bryozoans, and pentremites.

The best collection which has been made from the basal, oolitic limestone, has been made at the road corner just east of the Hopkinsville branch of the Illinois Central Railroad, a little over one-half mile northwest of McGowan Station.

The largest collection which has been made from the calcareous shale layers near the middle of the Paint Creek formation, is from a rather extensive glade about one-fourth mile north of the Sand Lick Road, a little more than one-fourth mile from the east boundary of the quadrangle. The species which have been identified are as follows:

Paint Creek Fauna from North of Clay Lick Road

Triplophyllum spinulosum (M.-E. & H.)
Amplexus sp.
Michelinia sp.
Pentremites pyriformis Say.
Pentremites godoni de France.
Pentremites sp. (*godoni* Ulrich, not de France).
Mesoblastus cf. *incurvatus* Weller.
Pterotocrinus sp. (wing plates).
Agassizocrinus sp.
Taxocrinus sp.
Crinoid stem (pentagonal).
Eridopora punctifera Ulrich.
Stenopora cestriensis Ulrich.
Anisotrypa symmetricus Ulrich.
Polypora sp.
Cystodictya labiosa Weller.
Crania chesterensis Miller and Gurley.
Schuchertella costatula (Hall and Clarke).
Orthotetes kaskaskiensis (McChesney).
Chonetes chesterensis Weller.
Productus inflatus McChesney.
Productus ovatus Hall.
Productus sp.
Productus cf. *parvulus* Meek and Worthen.
Diaphragmus elegans (N. & P.).
Camarotoechia purduei Girty.
Dielasma illinoisensis Weller.
Girtyella brevilobata (Swallow).
Girtyella indianensis (Girty).

Spiriferina transversa (McChesney).
Spiriferina spinosa (N. & P.).
Spirifer increbescens var. *transversalis* Hall.
Spirifer sp.
Reticularia setigera (Hall).
Eumetria vera (Hall).
Cliothyridina sublamellosa (Hall).
Composita trinuclea (Hall).
Conocardium sp.
Bellerophon sp.
Platyceras sp.
Phillipsia sp.
Fish tooth.

Many other smaller collections have been made from the shale beds at essentially the same horizon as the fauna recorded above, but as they all duplicate the above list to a greater or less extent, it will be unnecessary to present lists.

Correlation. A comparison of the fauna of the Paint Creek beds in the Princeton Quadrangle, with that of the same formation as far away as Monroe and St. Clair Counties, Illinois, shows very much in common. The formation is peculiarly the horizon of *Cystodictya labiosa,* a species which is present in great abundance. This bryozoan also does occur in the fauna of the Renault limestone, but never in such great numbers as in the Paint Creek. The species is unknown outside of these two formations. This formation in the Princeton Quadrangle is likewise a horizon of great abundance of Pentremites, and while there is some geographic variation exhibited by the members of the genus Pentremites in passing from place to place, there is a notable community of forms in the Paint Creek of the Princeton Quadrangle and that of the Mississippi River counties in Illinois. *Chonetes illinoisensis*, described originally from a Paint Creek fauna in St. Clair County, Illinois, is the only Chester species of the genus in western Illinois, and is known only from this horizon. In the Princeton Quadrangle it is likewise present, being the only Chester species of the genus, and it occurs only in this formation.

In their more recent writings both Butts and Ulrich[15] have used the name Gasper in place of Tribune, because of the unfortunate choice of the latter name. The typical Tribune is the same as the Paint Creek of the Princeton Quadrangle, but the typical Gasper is exposed farther east in Kentucky than the Princeton Quadrangle, and as described consists of two limestone members separated by the Sample sandstone member. The whole of the more typical Gasper is correlated by these authors with the Renault and Paint Creek limestones together of the western Illinois section, a correlation which seems to be wholly justified. The same authors consider the Paint Creek of the Princeton region to be the equivalent of the whole of the Gasper farther east, and consequently must find the equivalent of the Sample sandstone member within the 100 feet of the formation. In western Christian County, along the Princeton-Hopkinsville Pike, "Ulrich's type locality of the Tribune limestone," Butts [16] has designated a clay bed two to three feet thick as the equivalent of the Sample sandstone of Breckenridge County, and in this manner he is able to make two divisions of the Gasper such as are present in the more typical section. There is no reason whatsoever for dividing this "typical Tribune limestone" section, so far as the paleontological evidence is concerned, and the whole interpretation is based on the misconception of the true relationship of the Sample anl Bethel sandstones, which are really exactly equivalent. In Breckenridge County the true Renault fauna is present beneath the Sample sandstone just as it is present beneath the Bethel sandstone in the region east of Princeton, and the Paint Creek fauna is present in beds overlying these two sandstones in the two regions. Both Butts and Ulrich have assumed without reason that the "Upper Ohara" in the Princeton region is older than the Renault, therefore it is necessary for them to find some equivalent for the Renault in the formation they now call Gasper. The same men have recently determined that the Renault ("Upper Ohara") in Union County, Illinois, is Paint Creek in age,[17] a determination which is proven to be incorrect by reason of the beds having been actually traced and mapped in detail from the undisputed "Upper Ohara" farther east in Illinois, to the outcrop which they examined in Union County.

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[15] Ky. Geol. Surv., Miss. Form. West. Ky.

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[16] Ky. Geol. Surv., Miss. Form. West. Ky., p. 72.

[17] Bull. Geol. Soc. Amer., vol. 33, p. 832 (1922).

Both paleontological and stratigraphical evidence confirm the exact correlation of Ulrich's "Tribune limestone" of the section east of Princeton, with the Paint Creek formation of southern and southwestern Illinois, and with the upper division of the Gasper limestone of Breckinridge County, Kentucky.

One of the species which has been enumerated in the Paint Creek faunal list recorded on an earlier page, is *Camarotoechia purduei.* This is a rhynchonelloid brachiopod shell, a type which is unusual in the Chester fauna of southern Illinois and western Kentucky, and which is wholly unknown in most of the formations. In the locality where it has been found the species occurs in great numbers. It was originally described from the Moorefield shale of Arkansas, a Chester formation which has never been correlated with entire satisfaction with the Chester formations of the Illinois basin. The great abundance of the species in this Kentucky Paint Creek fauna suggests, at least, the correlation of the Moorefield with the Paint Creek. During the summer of 1920 a single specimen of *Liorhynchus carboniferum,* another species peculiar to the Morefield shale of Arkansas, was collected by the writer in Livingston County, Kentucky, from a limestone bed which was believed to be Golconda in age, suggesting the correlation of the Moorefield with the Golconda formation. From paleontological evidence at hand at the present time, the correlation of the Moorefield with either the Paint Creek or the Golconda, or perhaps with both these formations, can be assumed, but more certain determination of the age of the Arkansas formation must await additional knowledge of fossil faunas in Kentucky.

Cypress Sandstone

Name. This is not the Cypress sandstone of Ulrich's original report on western Kentucky, which, as has been shown, is in reality the Bethel sandstone. The Cypress was originally described by Engelmann from Cypress Creek in Union County, Illinois, and the formation has now been traced and mapped in detail clear across southern Illinois and into Kentucky. It is the formation which lies above the Paint Creek (Ulrich's original Tribune limestone), instead of the sandstone beneath it. In some parts of western Kentucky the Cypress is the bed which

Ulrich designated as bed No. 1 of the Birdsville, but, as will be shown, much of this Birdsville No. 1 is really the Tar Springs sandstone, occupying a much higher position in the section.

Distribution. Because of its limited thickness the Cypress is a much less important sandstone formation in the Princeton Quadrangle than it is farther west in Kentucky and in southern Illinois. Like the already described Chester formations its area of outcrop is in the belt extending to the northwest from the southeastern corner of the quadrangle, southwest of the main line of faulting The most extensive outcrops are south and southeast of Scottsburg, but it is also present along and west of the Farmersville road four miles northwest of Princeton. Some of the best exposures of the formation are present in the road between Scottsburg and Friendship.

Lithologic characters. The Cypress is a thinly bedded sandstone in the Princeton Quadrangle, of rather fine texture, the surfaces of the layers bearing ripple marks and other markings of shallow water conditions. The sandstone is commonly brown in color, or yellowish in some places.

Thickness. The total thickness of the Cypress sandstone has nowhere been observed fully exposed in the Princeton Quadrangle, in such a condition that it can be accurately measured. In the section at Walche's cut there are 30 feet of Cypress exposed, but the exposure is interrupted by a fault on the west, and the total thickness should probably be somewhat greater. The best locality for observing the extent of the interval between the top of the Paint Creek and the base of the overlying Golconda formation, is about a mile southeast of Scottsburg, and while the limits of the two bounding formations cannot be accurately fixed, the interval is clearly less than 40 feet, and the Cypress is probably about 30 feet thick at this place. Nowhere in the quadrangle is there any evidence that the formation exceeds 40 feet in thickness.

In his description of a "Section of the Chester Series in Caldwell County, east of Princeton, Ky.," Ulrich[18] has described the Cypress as a series of beds 163 feet in thickness, with 124 feet more as questionably Cypress, making 287 feet

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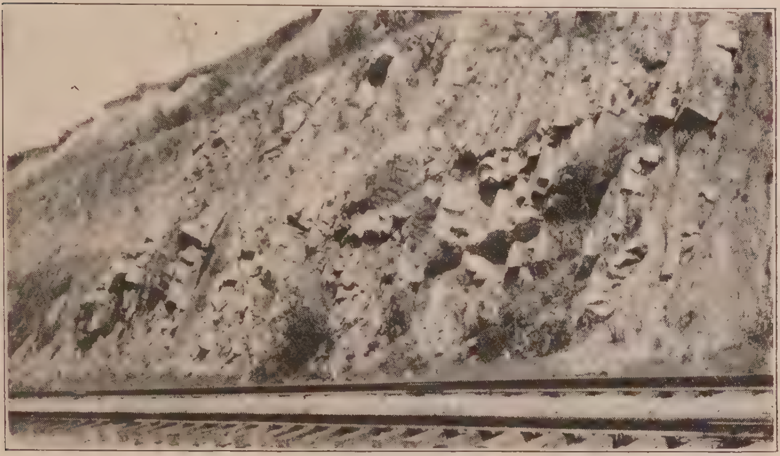
[18] Ky. Geol. Surv., Miss. Form. West. Ky., pp. 72-76.



STEEPLY INCLINED CYPRESS SANDSTONE

This view is in Walche's Cut, Illinois Central Railroad, east of Scottsburg, Caldwell County, Kentucky.

in all. This shows an utter misconception of the Chester section of the region on his part, and the sandstones which he has described, so far as he has described anything, belong to the Tar Springs formation rather than the Cypress. Indeed, the whole of Ulrich's so-called Birdsville bed No. 1 in the Princeton area, which should be the Cypress sandstone in accordance with his present conception, is Tar Springs sandstone, although the Birdsville No. 1 farther west, towards the Ohio River, is really the Cypress.

Stratigraphic relations. The stratigraphic relations of the Cypress with the underlying and overlying formations is not entirely clear in the Princeton Quadrangle. As has been indicated already, the alternation of thin limestone and sandstone members at the horizon of transition from the Paint Creek to the Cypress, especially as exhibited southeast of Scottsburg, suggests the absence of any relation of unconformity at the base of the formation. No unconformity between the Cypress sandstone and the overlying Golconda formation has been certainly established in the Princeton Quadrangle, although an unconformity at this horizon is widely present farther west in Kentucky and in southern Illinois.

Paleontology. No fossils of any sort have been observed in the Cypress sandstone in the Princeton Quadrangle, although it would not be unexpected to find fragments of plant remains, especially broken trunks of *Lepidodendron.*

Correlation. The correlation of the Cypress sandstone in the Princeton Quadrangle is established by its stratigraphic position between the certainly determined overlying and underlying formations on the basis of their contained fossils. These formations are unquestionably the Paint Creek below and the Golconda above, which establishes the position of the intervening sandstone as being the same as that of the typical Cypress sandstone in southern Illinois.

Golconda Limestone

Name. The Golconda formation has been named from excellent exposures in the Ohio River bluffs above the town of Golconda, Illinois. The name has been carried over into Livingston County, Kentucky, in the detailed mapping of the Golconda quadrangle, and it has been mapped in detail across much of Crittenden County. The presence of the formation in the Princeton quadrangle has been fully established by the fossil collections which have been secured.

Distribution. The Golconda is nowhere the surface formation under any considerable area within the Princeton quadrangle, although it is distributed in more or less isolated outcrops almost entirely across the quadrangle within the much faulted belt. The most extensive area of outcrop of the formation, within the limits of the quadrangle, is east of Scottsburg, between faults Nos. 74 and 76. The actual exposures in the area are really few, the best exhibition of the formation being three-fourths of a mile southeast of Scottsburg, and one-tenth of a mile northeast of the public road to Friendship, where the characteristic fossils of the formation can be collected in abundance. The formation must underlie the surface traversed by the Sand Lick road for three-fourths of a mile southeast from the crossing over the old line of the Illinois Central Railroad, but the actual exposures are limited to a few limestone ledges, more or less displaced, a little over one-half mile from the railroad crossing. Excellent exposures of some of the shale beds of the formation are present in the upper portion of the valley crossing the boundary between Otter Pond and Claxton rectangles, a little less than one and one-half miles west of the quadrangle boundary. Elsewhere within this area the presence of the Golconda is indicated by the low and flat topography and by the attitude of the overlying sandstone.

In the southeastern part of the Claxton rectangle the Golconda formation outcrops in the block bounded by faults 64, 65, 66, 70, and 45. The formation is present in the southern portion of this block, and is best exposed in the southwestern portion adjacent to fault No. 45, where the beds are steeply inclined, and have furnished a large and characteristic fauna. A narrow outcrop of the formation extends longitudinally through the middle of the fault block bounded by faults 57, 62, 63 and 45, the best exposure along this line being in Walche's cut, near its western extremity. A number of outcrops of the Golconda are present near the line between the Princeton and Claxton rectangles, over a distance of one and three-fourths miles north from the main road from Princeton to Dawson Springs. Along this belt the outcrops are really present in four distinct fault blocks, although there is no great dislocation between the different areas.

From three and one-half to four and one-half miles northwest of Princeton, near the road to Farmersville, the Golconda presents a narrow, band-like outcrop in the fault block bounded by faults 16, 17, 28, and 11. The best outcrops in this belt are in the southeastern part of the fault block. Other outcrops are present in the narrow, tilted fault block lying between faults 3 and 9 in the Flat Rock rectangle.

Lithological characters. Throughout the Princeton quadrangle, the Golconda is much more of a shale formation than a limestone, although in nearly every locality where the formation has been observed there are thin limestone layers intercalated in the shale. The shales differ more or less in character from place to place. In Walche's cut, nearly the whole formation is made up of black, fissile shale, elsewhere the shales are lighter in color, and in places they are more or less siliceous with some sandy layers. The limestone layers are also variable in character, but they are for the most part crystalline in texture, and vary from dark to light gray and brown in color. The beds are commonly thin, a foot more or less, and the maximum thickness observed is not over six feet.

In a number of the Golconda exposures which have been observed, there is a layer of hard limestone conglomerate, with some chert pebbles in places. This conglomerate bed does not occur at the base of the formation, but is commonly somewhere near the middle. In Walche's cut it is ten inches thick, and a similar thickness has been observed in a number of other localities. Its maximum development, so far as seen, is in a cut on the old line of the Illinois Central Railroad, where there are really two layers of the conglomerate separated by sandstone, the whole thickness being about five feet. Where weathered the conglomerate layer is more or less ferruginous, and commonly contains worn fossils, which in places are numerous.

Thickness. The maximum thickness of the Golconda formation, as it has been observed in the Princeton quadrangle, is 80 feet in the Walche's cut section. In some other places it cannot exceed 50 feet in thickness, and is even as thin as 30 feet in some of the sections studied. In the Walche's cut section over 60 feet of the entire thickness is black, fissile shale, in the midst of which is the conglomerate layer. The basal portion of the formation at this locality is a hard limestone.

Ulrich[19] has described the Golconda formation east of Princeton as a limestone with thick and thin shale partings with a thickness of 50 feet. He also expresses the opinion that some 124 feet of beds which are arenaceous in the main and which are believed by him to underlie the limestone and shale beds, are perhaps the equivalent of the lower portion of the Golconda as the formation is developed in its typical exposures. These arenaceous beds, however, are in fact a part of the Tar Springs formation and belong far above the Golconda in the Chester section.

Stratigraphic relations. In all probability the Golconda formation follows the Cypress sandstone without stratigraphic interruption. In Walche's cut most of the upper ten feet of the Cypress is thinly bedded. At the very top of the formation there is a three-inch layer of thinly laminated gray sandstone, followed by six inches of rusty, siliceous limestone. This limestone is followed by 18 inches of dark gray, carbonaceous shale which in turn is succeeded by 5 feet 11 inches of massive, gray, crystalline limestone. This succession seems to indicate that there may have been a somewhat gradual change in the character of sediments, from the arenaceous Cypress to the calcareous and shaly Golconda. In general, throughout the Ohio Valley, there seems to be no stratigraphic break in the section, and the chances are that the same conditions exist in the Princeton quadrangle. On the other hand, unconformity at the top of the Golconda has been clearly recognized at a number of localities in the Ohio Valley, both in western Kentucky and in southern Illinois, and although such a relation has not been certainly established in the Princeton quadrangle, the varying thickness of the Golconda suggests that such may be the situation. Furthermore it is established by the fossil faunas that it is the lower portion of the Golconda which is present in the quadrangle, a situation which would favor the absence of unconformity between the formation and the underlying Cypress.

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[19] Ky. Geol. Surv., Miss. Form. West. Ky., pp. 73-74.

Paleontology. Good fossils have been collected at a number of localities in the Princeton quadrangle. In the four principal areas of outcrop of the formation, the characteristic basal Golconda species, *Pterotocrinus capitalis*, has been found. Two distinct faunal assemblages have been recognized, one with the usual brachiopods, bryozoans and *P. capitalis*, the assemblage which is very characteristic of the basal Golconda from the Princeton quadrangle to Union County, Illinois. The second fauna is a molluscan fauna with many bellerophontids and some pelecypods, among which is the peculiar *Nucula platynotus*, a fauna which has been recognized here in the Princeton quadrangle, in Livingston County, Kentucky, in southern Johnson County, Illinois, and again in the basal Okaw limestone in Randolph County, Illinois.

The best representative collection of the usual *Pterotocrinus capitalis* fauna of the lower Golconda is from a locality three-fourths of a mile southeast of Scottsburg, where the following species have been recognized:

Fauna of the Golconda Limestone Near Scottsburg

Triplophyllum spinulosum (M. E. & H.).
Pentremites sp.
Pterotocrinus capitalis (Lyon).
Pterotocrinus sp. (wing plates).
Zeacrinus sp.
Eupachyrinus sp.
Echinoid spine.
Fistulipora excellens Ulrich.
Eridopora punctifera Ulrich.
Eridopora macrostoma Ulrich.
Meekopora clausa (Ulrich).
Stenopora tuberculata (Prout).
Fenestella cestriensis Ulrich.
Fenestella elevatipora Ulrich.
Archimedes communis Ulrich.
Archimedes compactus Ulrich.
Archimedes distans Ulrich.
Archimedes intermedius Ulrich.
Archimedes meekanus (Hall).
Archimedes proutanus Ulrich.
Archimedes swallovanus (Hall).
Archimedes terebriformis Ulrich.
Reteporina flexuosa (Ulrich).
Rhombopora tabulata Ulrich.
Streblotrypa nicklesi Ulrich.
Productus ovatus Hall.
Diaphragmus elegans (N. & P.).
Camarophoria explanata (McChesney).
Rhynchopora perryensis Weller.
Dielasma illinoisensis Weller.
Girtyella indianensis (Girty).
Girtyella brevilobata (Swallow).
Spiriferina transversa (McChesney).
Spiriferina spinosa (N. & P.).
Spirifer sp.
Eumetria vera (Hall).
Cliothyridina sublamellosa (Hall).
Composita trinuclea (Hall).
Sphenotus cf. *monroensis* Weller.
Euphemus randolphensis Weller.
Orthoceras sp.
Fish tooth.

The best exhibition of the *Nucula platynotus* fauna is from a locality east of Sulphur Creek, one and one-fourth miles southwest of Claxton. A collection from this locality has furnished the following species:

Fauna of the Golconda Limestone Near Claxton

Triplophyllum spinulosum (M.-E. & H.).
Pterotocrinus capitalis Lyon.
Pterotocrinus sp.
Echinoid spine.
Meekopora eximia Ulrich.
Stenopora cestriensis Ulrich.
Batostomella sp.
Fenestella (several species).
Archimedes intermedius Ulrich.
Archimedes lativolvis Ulrich.
Archimedes terebriformis Ulrich.
Polypora approximata Ulrich.
Septopora cestriensis Ulrich.
Rhombopora cf. *tabulata* Ulrich.
Lingula sp.
Glossina sp.
Orbiculoidea sp.
Orthotetes kaskaskiensis (McChesney).
Productus ovatus Hall.
Productus parvulus Winchell.
Diaphragmus elegans (N. & P.).
Girtyella indianensis (Girty).
Spiriferina transversa (McChesney).
Spiriferina spinosa (N. & P.).
Spirifer increbescens var. *transversalis* Hall.
Spirifer sp.
Eumetria vera (Hall).
Cliothyridina sublamellosa (Hall).
Composita trinuclea (Hall).
Spenotus rectangularis Weller.
Sphenotus (several species).
Nucula randolphensis Weller.
Nucula platynotus Weller.
Leda sp.
Parallelodon micronema (M. & G.).
Conocardium chesterensis Weller.
Schizodus depressus Worthen.
Cypricardella oblonga (Hall).
Bellerophon chesterensis Weller.
Euphemus randolphensis Weller.
Bucanopsis nodosus Weller.
Laevidentalium cf. *venustum* (M. & W.).
Plagioglypta sp.

Ptychomphalus (several species).
Mourlonia sp.
Ivania sp.
Murchisonia (several species).
Bembexia cf. *conicus* Weller.
Euomphalus sp.
Naticopsis sp.
Zygopleura sp.
Bulimorhpa sp.
Platyceras sp.
Orthoceras cf. *okawense* M. & W.
Phillipsia sp.

Smaller collections of Golconda fossils have been made from a number of other localities, but in every case they are of the usual species commonly found in the formation.

Correlation. The fossil faunas from the Golconda formation which have been recorded above establish conclusively that the beds in the Princeton quadrangle represent the lower portion of the formation, since both of the two faunal groups which have been recorded are wholly restricted to this horizon so far as they are known.

Ulrich[20] has expressed the belief that only the upper portion of the Golconda formation, as it is developed along the Ohio River, is present in the Princeton region of Kentucky, and that the lower Golconda is represented by a series of 124 feet of beds chiefly arenaceous in character, the alternative interpretation being that these arenaceous beds are the upper part of the Cypress sandstone. As already stated, however, it has been shown that all of these sandstone beds, described as Cypress or lower Golconda by Ulrich, are really a part of the much higher Tar Springs sandstone.

From the statements which they have made it seems doubtful whether either Ulrich or Butts have ever seen the Golconda formation in the Princeton area. If either of them had ever visited any of the good outcrops which exist at various localities, they could not have failed to detect the characteristic *Pterotocrinus capitalis* fauna, and if this fauna had been seen the mistake of considering the lower Golconda absent or represented by a series of sandy beds could not have been made.

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[20] Ky. Geol. Surv., Miss. Form. West. Ky., p. 73.

Hardinsburg Sandstone

Name. This formation was named by Butts[21] from outcrops in Breckenridge County, Kentucky. It has been recognized as a unit in the Chester Series throughout western Kentucky and across southern Illinois, even to Randolph County, where it is represented by local sandstone beds in the midst of the Okaw limestone.[22]

Distribution. The distribution of the Hardinsburg sandstone in the Princeton quadrangle follows closely that of the underlying Golconda formation. Wherever the Golconda is exposed this sandstone is present overlying it, and in addition the formation is present in the northwestern portion of the Claxton rectangle along Lambs Creek, the excavation of the creek valley not being sufficiently deep to expose the Golconda. Another small outcrop where the Golconda is not present is south of Hazelhurst School, along the northeast side of fault No. 42.

Lithologic characters. In the Walche's cut section the Hardinsburg formation is largely shale, much of which is arenaceous, but associated with it are some calcareous bands. The lowermost bed, 9 feet 3 inches thick, is a more or less massive sandstone with some thinly laminated shaly sandstone layers. Above the sandstone is a 10-inch layer of impure, siliceous limestone, and 18 feet 6 inches higher in the section is another similar limestone layer 7 inches thick. The remainder of the formation is shale, a part of which is interbedded with sandstone layers one-half to three inches thick. The higher portion of the formation has a number of thin siliceous limestone layers interbedded with the nearly black shales, the highest portion of the formation becoming somewhat more calcareous.

The formation as a whole is so shaly that it is commonly nearly hidden with talus, and this character, associated with the shaly nature of the underlying Golconda, does not permit the development of good exposures in the hillsides where the formation is known to be present. The basal, more massively sandy portion of the formation seems to be considerably thicker in some places than it is in Walche's cut, and where this condition exists there are better exposures of it. One of the best exposures of these sandstone beds which has been observed in the Princeton quadrangle is one and one-half miles east of Scottsburg, along the crossroad connecting the Princeton-Hopkinsville pike with Sand Lick road. There are also some fair exposures of the sandstone, more thinly bedded, than along the road last mentioned, along the western face of the hill lying between this road and Scottsburg.

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[21] Ky. Geol. Surv., Miss. Form. West. Ky., p. 96

[22] Weller, Jour. Geol., Vol. 28, p. 301 (1920).

Thickness. The thickness of the interval considered as Hardinsburg in the Walche's cut section is 61 feet 1 inch, but this is probably greater than the interval between the Golconda and Glen Dean formations in some other parts of the quadrangle. In some places the formation certainly does not exceed 40 feet, and it may be as thin as 20 feet in some places. There is always much uncertainty concerning the exact thickness of the formation because it is rarely well exposed, and the only section where its exact limits can be seen is in Walche's cut.

Stratigraphic relations. The stratigraphic relations of the Hardinsburg sandstone with the underlying Golconda formation have already been considered. Neither the presence nor the lack of an unconformity at this horizon can be established in the Princeton quadrangle, although it is quite certain that the Hardinsburg rests unconformably upon the Golconda in Livingston County, Kentucky, and across southern Illinois.

There seems to be no evidence whatever for considering that there was any interruption in sedimentation in passing from the Hardinsburg to the Glen Dean limestone. The shales of the Hardinsburg become more calcareous in their upper portion and pass over into the limestone beds of the lower Glen Dean.

Paleontology. In the higher portion of the beds which have been referred to the Hardinsburg formation in Walche's cut, the calcareous layers are fossiliferous, but the fossils are all poorly preserved and no attempt has been made to secure a representative fauna. No fossils at all have been observed in the sandstone beds of the formation, but fragmentary plant remains might be expected to occur.

Correlation. The correlation of the Hardinsburg sandstone has been established by the actual tracing of the formation, between the overlying and underlying limestones, throughout the region of its occurrence. Its lithologic characters change from place to place, but it is more or less of an arenaceous formation throughout, occupying the same stratigraphic position from Breckenridge County, Kentucky, to the Mississippi River.

GLEN DEAN LIMESTONE

Name. Butts named the Glen Dean limestone from exposures in Breckenridge County, Kentucky. The formation has been recognized wherever the Chester section has been carefully examined in western Kentucky, and it has been traced across southern Illinois to the Mississippi River.

Distribution. In the Princeton quadrangle the Glen Dean formation is closely associated with the underlying Hardinsburg and Golconda formations. In every one of the fault blocks where the Golconda is exposed the Glen Dean is also present, and in addition it is present in a number of places where the Golconda is not exposed. The most important of these latter outcrops is along Lamb's Creek between faults 33 and 50, where the Glen Dean forms the valley floor for much of the distance, but in the more northern portion of the stream's course, south of fault No. 33, the valley has been cut through the Glen Dean into the Hardinsburg, so that the Glen Dean itself outcrops on the valley sides. Throughout this Lamb's Creek valley, as elsewhere, the actual exposures of the Glen Dean are not common. The shaly character of the formation itself, associated with the shaly character of the two underlying formations, Hardinsburg and Golconda, and with the presence of a massive, basal sandstone bed in the lower part of the overlying Tar Springs formation, furnish a combination of conditions which tend to obscure the Glen Dean outcrop nearly everywhere. The most continuous exposure of the formation is in Walche's cut. The best exposures seen elsewhere are northeast of Princeton, near the road to Lewistown. In one tributary to Lamb's Creek from the west, just north of the Princeton-Lewiston road, one and one-half miles from Lewiston, the formation is well shown, but in other parts of the Lamb's Creek outcrop actual exposures are scanty. Another good exhibition of the formation is along a narrow belt one-fourth mile long, extending southward from the same Princeton-Lewistown road, a little less than two miles southwest of Lewistown. This last outcrop lies between faults 48 and 49.

A PORTION OF THE GLEN DEAN.

This massive limestone member in the lower portion of the Glen Dean formation may be seen in Walche's Cut, Illinois Central Railroad, east of Scottsburg, Caldwell County.

Lithologic characters. The larger portion of the Glen Dean formation in the Princeton quadrangle is shale, but at the base of the formation there is a massive limestone ledge, which in the Walche's cut section is 10 feet 11 inches thick. This bed is believed to be persistent throughout the area and of about uniform thickness. It is a very hard, tough limestone, somewhat crystalline, but in part compact and dense, gray in color. Following the basal limestone in Walche's cut there are 50 feet 9 inches of black, carbonaceous, fissile shale. This in turn is followed by 4 feet 4 inches of thinly bedded sandstone, then 2 feet, 8 inches of limestone. The next bed is 5 feet 2 inches of fine black fissile shale with a thin band of calcareous sandstone near the top. The uppermost, 13 feet 2 inches, consists of impure, gray limestones interberred with shales, the individual beds being from two inches to two feet in thickness. At no other locality in the quadrangle is the complete succession of beds in the Glen Dean exposed, but the lithologic character of the formation is somewhat uniform throughout the area. Wherever the formation is best exposed it is represented by more or less tumbled masses of limestone, which evidently are from the basal bed, and above these is a talus covered slope which is underlain by the more shaly portion of the formation.

Thickness. The measured section of Glen Dean in Walche's cut gives a total thickness of 87 feet, but this seems to be excessive when compared with the interval in other sections which can be occupied by the formation. About 40 feet seems to be the more usual thickness and in some places it seems to be even thinner than this.

Stratigraphic relations. There seems to be no distinct interruption of sedimentation in passing from the Hardinsburg sandstone below, into the Glen Dean. Interbedded with some of the sandy shales which constitute the upper part of the Hardinsburg, there are thin beds of impure limestone, showing that the conditions favored limestone sedimentation before the accumulation of the first massive bed of limestone which is considered as the base of the Glen Dean. Above the top of the formation there is an abrupt change from the shale and limestone sediments to the massive basal bed of the Tar Springs, and it is possible that the change may mean the presence of an unconformity, although such a relation cannot be certainly established from the observations in the Princeton quadrangle. The varying thickness of the Glen Dean formation, which seems to exist in the quadrangle, suggests that there may have been an interval of erosion preceding the deposition of the Tar Springs sandstone, which has removed a part of the Glen Dean in some places. Future observations may serve to confirm or establish the absence of an unconformity at this horizon, but at the present time the relation is uncertain.

Paleontology. Fossils are not abundant in the Glen Dean beds in the Princeton quadrangle, but in the interbedded limestone and shale member, at the top of the formation in Walche's cut, the following species have been collected:

Fauna of the Glen Dean Limestone in Walche's Cut

- *Amplexus* ? sp.
- *Pentremites brevis* Ulrich.
- *Pentremites canalis* Ulrich.
- *Pentremites* sp.
- *Eupachycrinus* sp.
- *Agassizocrinus* sp.
- *Pterotocrinus acutus* Wetherby.
- *Fistulipora excelens* Ulrich.
- *Eridopora punctifera* Ulrich.
- *Eridopora* cf. *macrostoma* Ulrich.
- *Cheilotrypa hispida* Ulrich.
- *Stenopora meekana* Ulrich.
- *Fenestella serratula* Ulrich.
- *Fenestella tenax* Ulrich.
- *Archimedes intermedius* Ulrich.
- *Archimedes communis* Ulrich.
- *Polypora tuberculata* Prout.
- *Polypora approximata* Ulrich.
- *Lyropora* sp.
- *Septopora subquadrans* Ulrich.
- *Ptilopora* sp.
- *Rhombopora persimilis* Ulrich.

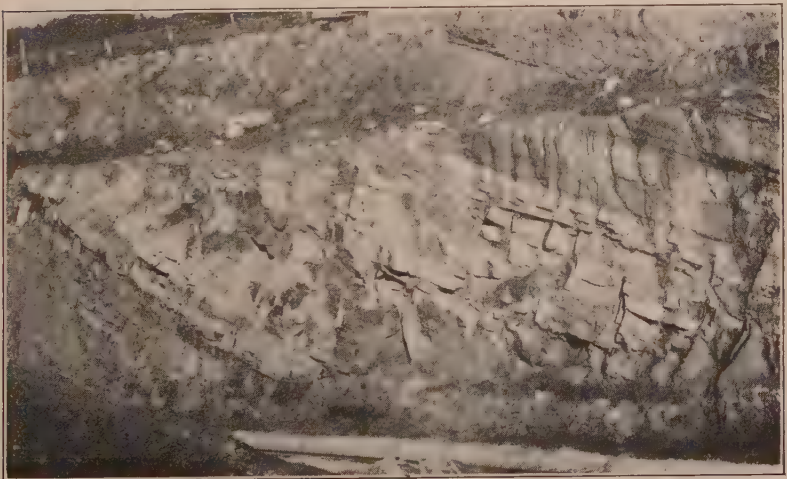
At one locality in the bed of Sulphur Creek, three-fourths of a mile southwest of Claxton, a ledge of massive limestone belonging to the Glen Dean formation, possibly the basal bed, is covered with an abundance of imperfect and fragmentary examples of a large species of Pentremites which seems to be *P. spicatus*, a characteristic Glen Dean species. At another locality in the bank of Lamb's Creek just west of fault No. 55, three-fourths of a mile southwest of Lewistown, there are ledges of Glen Dean limestone with an abundance of crinoid remains, among which are numerous wing plates of *Pterotocrinus acutus*. In many of the Glen Dean exposures fossils are not conspicuous, and if present are poorly preserved and fragmentary.

Correlation. The presence of such species as *Pentremites brevis*, *Pentremites spicatus*, and *Pterotocrinus acutus*, along with several of the species of bryozoans, is sufficient evidence for the determination as Glen Dean of the beds which have been so mapped in the Princeton quadrangle. These species are characteristic of this formation wherever they are known in western Kentucky and southern Illinois. Furthermore the stratigraphic position of the formation is that of the Glen Dean limestone, which has been traced and mapped in detail across the whole of southern Illinois and western Kentucky to the Princeton area.

Tar Springs Sandstone

Name. The Tar Springs sandstone was so named by Owen in Breckenridge County, Kentucky. In that part of the State there are bitumen bearing springs emerging from the formation, one of the largest of which is known as Tar Springs. In that county the formation overlies the typical Glen Dean limestone, and the name has been extended to the sandstone formation throughout western Kentucky and southern Illinois, which overlies that formation.

Distribution. Because of its greater thickness and the presence of more massive and less destructable sandstone beds, the Tar Springs sandstone occupies considerably larger areas than the three next older formations which are very largely shales in their composition. In some places in the Princeton quadrangle the Golconda, Hardinsburg and Glen Dean formations together underlie more or less steeply sloping hillsides,



BASE OF TAR SPRINGS SANDSTONE.

The view is in Walche's Cut, Illinois Central Railroad, east of Scottsburg.

and are capped by the more massive Tar Springs sandstone, which underlies much broader surfaces.

The formation is well exposed in a number of fault blocks in the complexly faulted area south of Claxton. Most of the more or less steeply dipping sandstone ledges in the several railroad cuts along the old line of the Illinois Central Railroad, a mile southwest of Claxton, are Tar Springs, and the hilltops in the fault block lying south of fault No. 64 are of the same formation.

The most continuous extensive area of outcrop of the formation is west and southwest of Lewistown, in several fault blocks which lie in general between faults 33, 46, 45, and 55. The valley of Lamb's Creek crosses this area in a general north-south direction, and has cut through the Tar Springs sandstone, exposing the underlying Glen Dean and Hardinsburg formations in the bottom of the valley, but the hills on either side are of Tar Springs sandstone. Other outcrops of the formation are present in several fault blocks north of Princeton, between faults 3 and 28. In this area, east of the Princeton-Farmersville road, much of the higher land is underlain by the Tar Springs sandstone, and in some of the smaller blocks the sandstone has been dropped to the level of the creek valley floor.

For a distance of about two miles northwest from the Princeton-Farmersville road, along the north side of fault No. 3, there is a narrow belt of Tar Springs sandstone in which the strata are dipping steeply to the northeast. Steeply dipping beds of the formation are also present along the northeastern border of the elongate, tilted block between faults 3 and 9. In a continuation of this same belt to the northwest, between faults 3 and 8, a sandstone formation alone has been observed which is believed to be the Tar Springs.

The only other area within the limits of the quadrangle which is underlain by the Tar Springs sandstone, is a narrow belt south of fault No. 1, extending westward from Flat Rock to the western border of the quadrangle.

Lithologic characters. The Tar Springs formation includes a number of more or less massive sandstone ledges which are separated by arenaceous shales, with one horizon of carbonaceous beds which becomes an impure coal in places. The best exhibition of the lower portion of the formation, about 76 feet, has been seen in the section at Walche's cut. At the base is a massive sandstone ledge 31 feet thick. This sandstone is a persistent member of the formation throughout the extent of its outcrop in the quadrangle. It is rather fine grained and light yellow in color, and in many localities in the quadrangle it is a distinct bluff making ledge, great masses of which have commonly slumped down over the underlying shale beds of the underlying formations. In many places the position of the outcrop of these earlier formations has been determined from the exposures of the massive basal bed of the Tar Springs.

In Walche's cut the massive basal bed of the Tar Springs is succeeded by a series of shaly beds, first 2 feet 8 inches of sandy shales, and then 15 feet 6 inches of black, carbonaceous shales, at the top of which there is a small amount of very poor coal. The carbonaceous bed is followed by more massive yellow sandstone, rather evenly bedded in layers 6 inches to 14 inches thick, the whole bed being 8 feet 7 inches thick. Above this there are 13 feet 3 inches of fissile shales, somewhat sandy in part, and this in turn is followed by 5 feet of thinly bedded yellow sandstone. This section does not constitute the entire thickness of the formation, the remainder of it being cut off by a fault which crosses the cut, the dislocation bringing the next succeeding formation, the Vienna limestone, against the lower part of the Tar Springs.

The higher portion of the Tar Springs sandstone is well exposed in some of the railroad cuts along the old line of the Illinois Central Railroad southwest of Claxton. In one of these cuts the formation can be seen passing beneath the Vienna limestone. The section at this place is an alternation of at least three rather massive ledges of fine-grained, yellow sandstone, the thickest one also the lowest one, being 20 feet 8 inches thick. The higher of the three beds is 4 feet 6 inches thick. Between the sandstone ledges there are thick beds of yellowish, thinly laminated, more or less sandy shales, the thickest bed being over 70 feet thick. The lowest beds in the section southwest of Claxton seem to be higher in position than the highest bed in Walche's cut.

The outstanding features of the formation as a whole is the succession of several massive sandstone ledges separated by more or less arenaceous shale members, with a carbonaceous or impure coal band some distance beneath the middle of the formation. The basal sandstone is the thickest and most massive, and in most places where it outcrops it is a bluff forming bed.

In his Chester section east of Princeton, Ulrich [23] has considered the Tar Springs sandstone beds exposed in the railroad cuts southwest of Claxton on the old line of the Illinois Central Railroad, as Cypress, and his published description of the Cypress is in the main a description of the Tar Springs.

Thickness. The complete thickness of the Tar Springs sandstone has nowhere been observed in one section in the Princeton quadrangle. In Walche's cut there are 76 feet of the lower portion of the formation exhibited, and in the cuts southwest of Claxton there are 120 feet 8 inches of the higher part, and it is believed that there is no overlapping of the two sections, which would give a thickness of at least 198 feet 8 inches, with the possibility of some additional beds not represented in either section. A thickness of perhaps 200 feet may be assumed as the minimum for the formation.

In the high hill south of fault No. 31, and just east of Lamb's Creek, the Tar Springs formation must occupy 120 feet or more of the total height, this being the lower portion of the formation resting upon the Glen Dean limestone. At the base the massive, bluff forming sandstone ledge is well exposed, but the higher strata are much talus covered.

Stratigraphic relations. The abrupt introduction of the massive sandstone beds of the Tar Springs, along with the apparent variation in thickness of the underlying Glen Dean, this variation being in the upper beds of the formation, suggests the possibility of a relation of unconformity between the two formations.

In the higher portion of the Tar Springs formation the sandstone members become thinner and the shale beds more conspicuous, and although the actual transition into the overlying Vienna limestone has not been observed, it is not improbable that the passage is accomplished with no break in the sedimentation, and consequently with no unconformity.

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[23] Ky. Geol. Surv., Miss. Foss. West. Ky., pp. 74-75.

Paleontology. No fossils other than the fragmentary plant remains have been observed anywhere in the Tar Springs formation in the Princeton quadrangle.

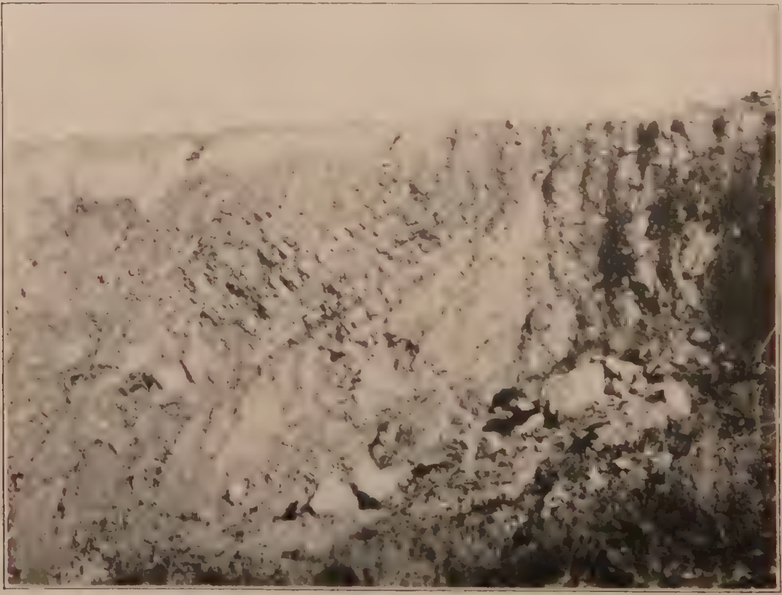
Correlation. The correlation of the Tar Springs sandstone in the Princeton quadrangle is based primarily upon its stratigraphic position above the Glen Dean limestone, which is characterized by its peculiar assemblage of fossil species. A characteristic of some significance, however, may be the impure coal bed which is present in the Tar Springs exposure in Walche's cut. A similar coal bed has been recognized in the formation at a number of localities in western Kentucky and southern Illinois, and seems to be a very persistent feature of the formation. It is not possible to determine whether this Tar Springs coal bed was deposited contemporaneously throughout the whole southern Illinois and Kentucky section, but it is possible that such was the case.

Vienna Limestone

Name. This formation was named from Vienna, Johnson County, Illinois, and it has been recognized as a persistent unit in the Chester section over much of southern Illinois and in western Kentucky.

Distribution. In the Princeton quadrangle the Vienna limestone outcrops only to the northeast of the main line of faulting which crosses the area. Perhaps the best exposure in the district is in Walche's cut, where the formation is faulted against the lower portion of the Tar Springs sandstone. An exposure may be seen in one of the valleys between cuts on the old main line of the Illinois Central Railroad, southwest of Claxton, where it overlies the Tar Springs sandstone in its normal position. The formation is well exposed at Lewistown, also north and south of that place at a number of localities, just above the Tar Springs. In the northwestern part of the quadrangle the characteristic chert beds of the formation are exposed at a number of localities about Farmersville, where the Vienna seems to be the lowest exposed formation. It is again exposed at a number of points adjacent to the upper boundary of the steeply dipping Tar Springs sandstone belt along fault No. 3, west of the Princeton Farmersville road. Other exposures may be seen in the vicinity of Flat Rock, where the upper boundary of the Tar Springs is present.

Lithologic characters. The Vienna has two distinct members which seem to be present wherever the formation comes to the surface in the Princeton quadrangle, these being a highly cherty limestone below and a shale above. The position of outcrop of the lower member of the formation is commonly established by the presence of the residual chert which occurs in abundance along with the residual clay of the formation. Such residual cherts are conspicuously present along the public highways wherever the roads cross the formation, along streams and in fields. The actual exposures of the limestone with the inclosed cherts are less commonly met with, but where it has been seen the limestone is gray in color, and more or less massive and compact in texture, or subcrystalline.



THE TRUNCATING EFFECTS OF EROSION.
Weathered Vienna Limestone, Walche's Cut, Illinois Central Railroad, east of Scottsburg.

The chert commonly occurs in more or less continuous layers from one to three inches in thickness, which break up on weathering into subcubical fragments with dimensions equal to the thickness of the layer from which they come. In places the limestone itself is highly siliceous, and upon weathering the lime is leached out, leaving a porous, siliceous rock, yellow in color. The lithologic character of such leached beds is identical with similar beds of the same formation which are found so characteristically in the Vienna limestone in Johnson and Union Counties, Illinois. The similarity in this lithologic character of the formation in such widely separated localities is really remarkable. One excellent exposure of the formation in the south side of Walche's cut gives a good exhibition of interbedding of the characteristic leached limestone and chert bands.

The shales which constitute the upper portion of the formation are rather thinly laminated and fissile in character, argillaceous and free from sand, and dark blue or almost black, to gray in color.

Thickness. The best section in the Princeton quadrangle from which to determine the thickness of the Vienna limestone is that in Walche's cut, where 54 feet of strata are referable to it, both the lower more calcareous beds and the higher shaly beds being well exposed. At no other locality in the quadrangle can the lower and upper limits of the formation be determined with any degree of accuracy, but the thickness of the formation probably remains rather constantly at about 50 feet.

Stratigraphic relations. There is no reason to conclude that the Vienna is not in conformable contact with the formations both below and above it. Its actual contact with the Tar Springs sandstone has not been observed in the quadrangle, although the exposure in Walche's cut is believed to extend essentially to the base of the formation. It is known that the Tar Springs becomes more shaly in its upper portion, and it is more than likely that the transition to the Vienna takes place without any break. The transition from the Vienna to the overlying Waltersburg is well shown in the Walche's cut section, and there clearly was no interruption in the sedimentation in passing from the lower to the higher formation.

Paleontology. The calcareous beds of the Vienna and some of the thinner layers of shales interbedded with them are more or less fossiliferous. The fossils, however, are commonly fragmentary and consist largely of bryozoans of the more usual Chester types. No complete collections have been made from the formation.

Correlation. The correlation of the Vienna formation in the Princeton quadrangle has been based essentially upon its stratigraphic position, and upon its peculiar lithologic character, and in the absence of opportunity for the detailed study of fossil collections from the formation, these features seem to be sufficient evidence to establish the identity of the formation with the typical Vienna of southern Illinois.

WALTERSBURG SANDSTONE

Name. The Waltersburg sandstone was first named from exposures in Pope County, Illinois. The formation has been found to be a persistent one across southern Illinois from the western part of Hardin, to Union County. The formation has been recognized in one locality in Livingston County, Kentucky, and is now found to be more widely distributed and quite typical, in the Princeton quadrangle.

Distribution. This formation has been found to be co-extensive with the underlying Vienna limestone in the Princeton quadrangle. Wherever the cherty Vienna limestone is present, there is some evidence of a thin sandstone formation overlying it, separated by a thin shale interval, which is the Waltersburg.

Lithologic characters. The Waltersburg varies somewhat in its characteristics from place to place, within the Princeton quadrangle, and in some places, as Walche's cut, it contains a considerable proportion of shale. Where the greater amount of shale is present in the formation, the sandstone is in thin beds distinctly jointed in two directions, one set of joints being close together, commonly three inches or less, and the other set 12 to 20 inches apart. Jointing of this sort causes the beds, which are only two or three inches thick, to break up into elongate, splinter-like fragments which are very characteristic of the formation. In situations where these splintery beds have not been subjected to weathering, as in Walche's cut, the sandstone is dark in color upon freshly fractured surfaces, the outer surfaces of the beds being reddish brown. In more weathered situations the sandstone has been subjected to leaching and is yellowish in color. In many places where the public highways in the quadrangle have crossed the Waltersburg formation, these fragments of sandstone, like sticks of stovewood, are conspicuous across the outcrop.

In some places the Waltersburg is more completely sandstone in composition, in which case the formation is thinly bedded and commonly rather pale yellow in color. Even in exposures of this sort there is a tendency towards the development of the splinter-like fragments where the beds are broken up, but this type of jointing is less perfectly developed.

The type of jointing, and the consequent form of the residual sandstone fragments of the Waltersburg, which has been described in the foregoing paragraphs, is not limited to the formation in the Princeton quadrangle, but occurs also in the same formation as far away as Pope and Johnson Counties, Illinois. It is really remarkable that such a peculiar characteristic of the formation should be so persistent over so great an area. Where the formation has its greatest development, near the line between Pope and Johnson Counties, Illinois, it is a massive, bluff forming sandstone 60 or more feet thick. This expression of the formation, however, is very limited in an east-west direction along the outcrop, and where it is traced to the east and to the west, it changes in a short distance into thin, splintery sandstone layers entirely like the beds in the Princeton quadrangle.

Thickness. The Waltersburg is one of the thinner formations of the Chester Series in the Princeton quadrangle, in the Walche's cut section there being only 6 feet 8 inches of beds which can be referred to it. At this locality there are two splintery sand beds such as have been described, each 1 foot 4 inches thick, separated by four feet of black shale. Where the formation is more completely sandstone it is somewhat thicker, but probably nowhere does it exceed 15 or 20 feet.

Stratigraphic relations. From the evidence afforded by the fully exposed section in Walche's cut, there seems to be no reason for recognizing any interruption in sedimentation either below or above the Waltersburg sandstone.

Paleontology. No fossils have been observed in the Waltersburg, although it is not at all unlikely that some imperfect plant remains may occur in the formation in places.

Correlation. The basis for correlating these beds in the Princeton quadrangle with the Waltersburg formation of Pope and Johnson Counties, Illinois, is its identical stratigraphic position, as determined especially by the overlying, highly fossiliferous Menard limestone, and by the remarkable similarity in lithologic characters of certain exposures of the formation in the two regions.

MENARD LIMESTONE

Name. The Menard limestone was named from Randolph County, Illinois, where the formation is well exposed in the Mississippi River bluffs at Menard. The formation has been mapped across southern Illinois and into Kentucky. It is one of the more important of the Chester limestone formations, and is persistent in its lithologic and faunal characteristics.

Distribution. The Menard limestone is exposed in a number of the fault blocks south of Claxton, and also occupies a considerable area northeast and south of Lewistown, between faults 31 and 53. A smaller area, continuous with the last mentioned on one side, and with the larger of the blocks south of Claxton on the other, is present in the fault block bounded by faults 50, 55, 56, 45, and 54. By far the largest outcropping area of the formation is in the northwestern portion of the quadrangle, between faults 1, 2, and 3. Excellent exposures of the formation can be seen in all directions from Farmersville, on the east to Big Cany Creek on the north and south to the faults, and on the west to the border of the quadrangle.

Lithologic characters. The lower portion of the Menard formation contains a considerable amount of shale interbedded with the limestone beds, which vary in thickness from a few inches to a foot or more. This portion of the formation is rarely well exposed in natural outcrops, because of its lithologic character, it being more or less completely talus covered, or is covered with residuum. The only locality where the basal part of the formation is well exposed is in Walche's cut. Some of these lower beds are abundantly fossiliferous, and in places the fossils have been silicified and occur in well preserved condition in some of the residual clays.

The higher portion of the formation is made up of more massive limestone beds, but these beds are commonly separated by shale partings from a few inches to several feet thick, the limestone ledges themselves varying in thickness up to 10 feet or more. The limestone is for the most part gray in color, and on weathering it commonly has smooth surfaces. The texture of the rock is in most places compact and little or not at all crystalline, it is hard and brittle, and breaks with a splintery fracture. Some beds are darker colored than others, and more compact, but on the whole there is a notable similarity throughout.

In some parts of the quadrangle there is apparently a thin sandstone member near the upper part of the formation, but in much of the area of outcrop such a member seems to be lacking.

Thickness. In Walche's cut the lower shaly portion of the Menard is approximately 30 feet thick, but the thickness of the remaining beds is not certainly determinable. In the northwestern part of the quadrangle, however, at a number of places, there is an interval of 120 feet which must be occupied by the Menard limestone, and the whole formation may have a maximum thickness of 140 feet within the quadrangle.

Stratigraphic relations. There seems to be no interruption in the accumulation of sediments in passing from the underlying Waltersburg sandstone into the Menard limestone. At the top of the formation, however, there may be an unconformity. This condition is suggested by the abrupt change from limestone to sandstone sediments, and there seems to be some variation in the thickness of the Menard, which may be due to erosion preceding the deposition of the overlying Palestine sandstone. At some localities in southern Illinois there is an undoubted unconformity at this horizon, and it is quite likely that the condition persists into Kentucky.

Paleontology. The fossils of the Menard limestone are most abundant and best preserved in the lower part of the formation, in the more shaly beds. In the more dense limestone beds of the higher portion of the formation, the fossils are commonly so firmly imbedded that they are not easily collected or identified, and they are also much less numerous than in the lower beds. A characteristic fauna from the lower Menard has been collected from the exposures in Walche's cut, and the following species have been recognized:

Menard Fauna from Walche's Cut

Triplophyllum spinulosum (M.-E. & H.).
Pentremites fohsi Ulrich.
Pentremites sp.
Pentremites sp.
Agassizocrinus sp.
Pterotocrinus menardensis Weller.
Archaeocidaris sp. (spine).
Fistulipora excelens Ulrich.
Stenopora cestriensis Ulrich.
Stenopora tuberculata Prout.
Anisotrypa solida Ulrich.
Fenestella cf. *multispinosa* Ulrich.
Archimedes distans Ulrich.
Archimedes intermedius Ulrich.
Archimedes cf. *swallovanus* Hall.
Polypora corticosa Ulrich.
Orthotetes kaskaskiensis (McChesney).
Productus ovatus Hall.
Diaphragmus elegans (N. & P.).
Spiriferina transversa (McChesney).
Spiriferina spinosa (N. & P.).
Spirifer increbescens Hall.
Cliothyridina sublamellosa (Hall).
Composita subquadrata (Hall).
Allorisma clavata McChesney.
Conularia sp.

The larger number of the species mentioned in the above list are more or less widely distributed through the Chester faunas, but the large forms of *Spirifer increbescens* and *Composita subquadrata* are characteristic of the higher Chester faunas, and *Pentremites fohsi* and *Pterotocrinus menardensis* are limited to the Menard, so far as known, and are the most diagnostic species for this lower part of the formation.

A number of other collections from the Menard limestone have been made in the quadrangle, all of them containing the usual species found in the formation, *Spirifer increbescens* and *Composita subquadrata* generally being the most common members of the faunas. The species *Sulcatopinna missouriensis*, which is a common Menard species in much of southern Illinois, has been collected from a number of places, but the species has not been observed to be so common here as it is in some other areas.

Correlation. The correlation of the Menard in the Princeton quadrangle is fully established by the presence of the fauna characterized by *Pentremites fohsi* and *Pterotocrinus menardensis*, which are good zonal fossils for the lower Menard, being characteristic of this horizon across southern Illinois and elsewhere in Kentucky, and being unknown from any other position. Along with the faunal evidence which is so conclusive, the lithologic similarity of the formation with the Menard elsewhere in western Kentucky and southern Illinois, gives additional strength to the correlation of these beds in the Princeton quadrangle.

Palestine Sandstone

Name. The name Palestine has been used widely in southern Illinois and western Kentucky for one of the higher sandstones of the Chester Series. It was named from a locality in Randolph County, Illinois, where the typical exposures are to be found. It is the first one of the Chester sandstones which is developed uniformly across southern Illinois from the Ohio to the Mississippi Rivers, and the studies in western Kentucky have shown that it continues with similar uniformity at least as far as the Princeton quadrangle.

Distribution. Most of the Palestine sandstone in the Princeton quadrangle is present within a belt crossing the area in a northwest-southeast direction, from the eastern border near Claxton to the northern border two miles east of Flat Rock. Outside of this belt the formation occurs southwest and west of Farmersville, capping a number of hills near fault No. 3. Within the diagonal belt above mentioned the sandstone does not occur as a continuous outcrop. South of Claxton there are two small areas of outcrop in two separate fault blocks, but aside from these all the outcrops occur in two of the larger fault blocks, one between faults 56 and 33, the other between faults 6 and 1. These two areas are separated by the down-dropped block of Pottsville between faults 33 and 6. The more extensive outcrop of the formation is present in the block between faults 6 and 1, where its greatest width is nearly three miles towards the south border of the fault block. North of Briarfield Church the Palestine caps the hills west of Big Cany Creek, and northwest of Rufus the outcrop becomes more extended northeast of the same creek. A number of hills north of Farmersville, towards Big Cany Creek, are capped by isolated outcrops of the formation, and other hills east, southwest and west of Farmersville are similarly capped by the formation. The largest of these hill-capping outcrops is situated north of Good Spring School.

Lithologic characters. In general the Palestine is a brown to yellow sandstone, in places with a decidedly pink tint. In texture it is rather fine and uniform. It is made up of more or less massive beds in parts of the formation, elsewhere it is thinly bedded, in places almost shaly in character. It is not notably different from the other more massive beds of sandstone in the Chester Series of the region, and exhibits no lithologic character which would serve to identify it with certainty in situations where its stratigraphic position relative to the limestones of the series could not be determined.

Thickness. Where its full thickness can be best determined, the Palestine sandstone seems to be approximately 60 feet thick. There are localities where the formation does not seem to be over 40 feet in thickness, the thinest exhibition of it being east of Big Cany Creek, southeast of Rufus.

Stratigraphic relations. The possibility of an unconformity between the underlying Menard limestone and the Palestine sandstone has already been mentioned. At the top of the formation there is no evidence exhibited within the quadrangle, so far as observations have been carried, to either establish or disprove the presence of a stratigraphic break between it and the overlying limestone. Throughout western Kentucky and southern Illinois this horizon is generally obscure, but at a few localities it seems to be clear that there was no interruption in sedimentation at this horizon, and it is quite likely that this is the condition throughout.

In the east central portion of the quadrangle, at two localities, one a mile and one-half northeast of Claxton, the other a mile northwest of Lewistown, the higher beds of the Chester have been eroded before the deposition of the Pottsville sandstone of the Pennsylvanian, so that the Pottsville rests unconformably upon the Palestine sandstone.

Paleontology. As in other sandstones of the Chester Series, the only fossils which are likely to be met with in the Palestine, are fragmentary plant remains, broken trunks of a species of *Lepidodendron* being the most common. Even these fossils have not been observed in the Princeton quadrangle, although they may well be present somewhere, and are likely to be met with if farther search is made. With our present knowledge even the plant remains, if they should be found, would serve to be of little value for purposes of correlation, for the same things seem to occur in the several sandstones of the series.

Correlation. The correlation of the Palestine sandstone in the Princeton quadrangle is dependent wholly upon its stratigraphic position between the Menard and Clore limestones. A similar sandstone occupies this position throughout western Kentucky and southern Illinois, and it is undoubtedly a continuous bed spreading from western Kentucky to Randolph County, Illinois.

Clore Limestone

Name. The Clore limestone is another formation which was originally named in Randolph County, Illinois. It has been traced across southern Illinois and western Kentucky as far as the Princeton quadrangle.

Distribution. The Clore limestone occupies a narrow belt of outcrop, overlying the Palestine sandstone, extending from near Claxton in a northwest direction to the northern border of the quadrangle about six miles east of the northeast corner. Another similar outcropping belt, about one and one-half miles in length, also having a northwest-southeast direction, lies a little west of Bethany School.

Throughout its whole extent the Clore is commonly rather poorly exposed, being so situated that it is likely to be more or less covered with talus from the overlying beds. Along a portion of the main belt of outcrop of the formation, for a short distance northwest of Claxton, and again northeast of Lewistown, the Clore formation, along with all the higher beds of the Chester series, have been eroded before or during early Pennsylvanian time, so that the Pottsville formation rests upon the underlying Palestine sandstone.

Lithologic characters. The Clore formation consists of interbedded limestone and shale. The relative proportion of the two types of sediments is not easily determined because of the usual talus covering which obscures the formation in most places, but there is probably more shale than limestone. The limestone is more or less variable in character, but the beds most commonly exposed are in general light to dark gray in color, hard and more or less brittle, and compact in texture. The beds weather with smooth surfaces, which are likely to be somewhat lighter colored than the freshly broken surfaces. The limestone beds of the Clore are not unlike similar beds which occur in the Menard limestone below, or in the Kinkaid limestone which occupies a still higher position.

Thickness. It is somewhat difficult to determine with any accuracy, the thickness of the Clore formation in the Princeton quadrangle. Perhaps the most satisfactory localities to estimate this thickness are along that portion of the outcrop extending northwest and southeast from Peach. In this district there is an interval above the Palestine sandstone as great as 60 feet which may be occupied by the Clore. This amount would be the maximum, and in all probability the actual thickness is somewhat less. Elsewhere in the quadrangle there seems to be less room for the formation, where it may be only 30 to 40 feet thick. Throughout the whole extent of the formation, from the Mississippi River sections in Illinois, to that portion of Kentucky covered in this report, the thickness of the Clore formation varies from 30 to 60 feet, about 40 to 50 feet being the more usual thickness, so that the thickness of the formation in the Princeton quadrangle agrees very well with that exhibited elsewhere.

Stratigraphic relations. Continuous exposures of this portion of the Chester Series are not met with in the Princeton quadrangle, so that little can be determined regarding the stratigraphic relations of the Clore formation, either with the underlying Palestine or with the overlying Degonia sandstone. Nowhere in southern Illinois or in Kentucky have any facts been observed in connection with the formation to establish relations of unconformity between it and either the underlying or overlying sandstones, and in all probability the sedimentary succession is unbroken at both of these horizons.

Paleontology. Throughout the extent of the Clore limestone in southern Illinois and western Kentucky, the presence of delicate cylindrical bryozoans belonging to the genus *Batostomella,* have been observed very generally in some portion of the formation. The species commonly met with is *B. nitidula,* and although this and perhaps other similar Clore species are present elsewhere in the Chester Series, they seem to be most abundant in some beds of the Clore. Another species which to the present time has only been observed in the Clore formation, is a large species of *Productus,* probably undescribed. In the Princeton quadrangle the large *Productus* has not been observed, but the common presence of examples of *Batostomella* has been met with in at least one locality near the southwestern corner of the Tradewater rectangle. Systematic search for a good collection of the Clore fossils has not been made, however, and it is not unlikely that representative collections may be secured at some future time.

Correlation. So far as any paleontological evidence has been secured, it substantiates the correlation of this unit in the Princeton quadrangle with the Clore throughout western Kentucky and southern Illinois, but such evidence, so far as it has been gathered to date is insufficient. The position of this stratigraphic unit in the regular Chester sequence, however, its thickness and general lithologic character, seem to fully warrant the reference of the bed to the Clore formation.

DEGONIA SANDSTONE

Name. The Degonia sandstone was named from Jackson County, Illinois, where the formation is an important cliff forming member of the Chester Series in the Mississippi River bluffs. The formation has been recognized and mapped across southern Illinois and also in the adjacent portion of western Kentucky, and is now known to extend at least as far east as the Princeton quadrangle.

Distribution. The distribution of the Degonia sandstone in the Princeton quadrangle follows closely that of the underlying Clore limestone. In most parts of the area it is a narrow belt because of the limited thickness of the formation. In many places the exposures are poor, but in most sections the residual blocks of sandstone very definitely mark the position of the outcrop. Perhaps the most extensive exposure of the formation is along the road leading north from Princeton to Liberty School, where for nearly a mile north from Peach this sandstone is exhibited in numerous exposures.

Lithologic characters. The Degonia is similar in character to much of the other sandstone of the Chester Series in the Princeton quadrangle, and it possesses no distinctive features by means of which it can be certainly recognized, apart from its stratigraphic position. It is fine grained, light yellow to brownish in color, and rather thinly bedded.

Thickness. The Degonia is one of the thinner sandstones in the Chester Series of the Princeton quadrangle. None of the outcrops are such that the whole of the formation can be observed and measured direct, but in certain places the possible limits of the formation can be established with some degree of accuracy. Nowhere in the area does it seem to exceed 30 feet in thickness, and in places it is probably 20 feet or less.

Stratigraphic relations. There are no data at hand to show that the Degonia sandstone in this region is unconformable with either the underlying or overlying formations.

Paleontology. No fossils of any sort have been observed in this sandstone in the area under consideration, but it is not at all unlikely that more or less fragmentary remains of plants may be discovered in the formation.

Correlation. The correlation of the Degonia sandstone in this part of Kentucky is based entirely upon its stratigraphic position between the Clore and Kinkaid limestones whose equivalence with the limestones of southern Illinois is established with certainty by their fossil contents.

KINKAID LIMESTONE

Name. The name of this limestone was derived from Kinkaid Creek in Jackson County, Illinois. It is one of the more important limestones of the Chester Series, and in much of its extent from the Mississippi River to western Kentucky it is the thickest limestone of the whole series.

Distribution. In the Princeton quadrangle the greatest extent of the Kinkaid limestone is present along a belt extending northwest from Claxton to about the middle of the north boundary of the quadrangle, this belt being interrupted for the distance of about one and one-half miles by the down-dropped block of Pottsville sandstone between faults 7 and 33. The next largest area of outcrop is in the extreme northwestern corner of the quadrangle, north of fault No. 1, where the formation occupies the floor and sides of the valleys, being overlain by the Pottsville. A third area of outcrop is in the truncated, wedge-like block which is down-dropped between faults 5, 3, and 6, and adjacent to this on the south is a small area between faults 3 and 6, in the valley of a tributary of Phelps Creek, which is exposed by erosion of the overlying Pottsville. Farther to the east, along Phelps Creek, the Kinkaid is exposed in the elongate trapezoidal fault block bounded by faults 3, 24, 25, and 33.

Along a part of the main belt of outcrop of the formation, extending northwest from Claxton, the pre-Pottsville erosion was sufficient to remove the entire thickness of the Kinkaid, as well as the underlying Degonia and Clore formations, so that the Pottsville sandstones rest upon the Palestine sandstone. Where the Pottsville rests upon formations older than the Kinkaid there is of course an interruption in the continuity of the outcrop of the limestone, two such interruptions being present, the larger one a mile and one-half northwest of Claxton, and the smaller one a mile east of Lewistown.

Lithologic characters. The Kinkaid formation is an alternating series of limestone and shale beds, varying in thickness and in lithologic characters. The best exposures of the formation are situated on more or less steeply sloping hillsides, and in ledges which border some of the streams which cross the belt of outcrop. The hillside outcrops are commonly represented by partially exposed ledges and by slumped masses of limestone, the actual exposures of shale beds being unusual. Because of the nature of the exposures and the amount of talus covering, it has not been possible to construct a detailed section of the whole formation.

The several limestone members of the formation differ more or less in character and thickness. In general they are very evenly bedded, in any one member the beds commonly being somewhat uniform in thickness, and being separated by shaly partings. Some of the limestones are light-gray in color, weathering with smooth surfaces, hard and compact in texture, breaking with splintery fracture, not unlike much of the Menard limestone. Other beds are more argillaceous with more conspicuous shaly partings between the individual layers. None of the beds observed are notably crystalline in character. The shale members are probably as variable in character as the limestones, but they are not so readily observed. Some beds are more or less calcareous, others are wholly argillaceous, and they vary in color from black or nearly black to light gray. Some beds are quite fissile in character, others are more massive.

In the lower portion of the formation there seems to be present in most or all sections, a thin sandstone member. In character this sandstone is not unlike other Chester sandstone beds, but the actual exposures are obscure, and it is commonly represented by more or less scattered residual blocks upon the hillsides. A similar sandstone member has been observed in the Livingston County, Kentucky, section.

The Kinkaid section in the Princeton quadrangle differs notably from that of Livingston County, and much of southern Illinois, in the absence of a conspicuous chert bed near the base of the formation, beneath the sandstone member. There is, however, a considerable amount of chert in places associated with the formation at its very summit. This chert bed has nowhere been observed *in situ*, it occurs in the form of loose, irregular masses upon the hill slopes at or just beneath the line of contact between the Kinkaid and the overlying Pottsville, and it is not improbable that they were originally masses of residual chert upon the pre-Pennsylvanian land surface. This chert horizon is by no means so conspicuous as that in the lower part of the formation farther west, nor is it so conspicuous a chert zone as the Vienna limestone within the Princeton quadrangle.

Thickness. In view of the fact that the pre-Pennsylvanian erosion has in places removed the entire Kinkaid formation, and the underlying Degonia and Clore, the actual thickness of the formation in the Princeton quadrangle varies from zero to the maximum amount present, which may be as much as 100 feet. This thickness is not as great as in some localities farther west, in Kentucky and Illinois, where as great a thickness as 180 feet or even 200 feet is known in certain sections.

Stratigraphic relations. The stratigraphic relations between the Kinkaid limestone and the underlying Degonia sandstone have already been considered. At the summit of the formation there is everywhere a great unconformity between the Chester Series and the Pennsylvanian.

Paleontology. In many places the limestones of the Kinkaid formation are not conspicuously fossiliferous. Where fossils are present they are for the most part brachiopods of the usual Chester types, great numbers of individuals of Composita and Spirifer being present in some localities, with lesser numbers of other genera of brachiopods, and some molluscs. The bryozoans are much less conspicuous in the Kinkaid than in other Chester limestones, although some of the usual Chester genera such as Archimedes, etc., are locally present. Crinoidal remains are also less commonly present than in most of the other limestones of the series.

A characteristic Kinkaid fauna from a locality three-fourths of a mile west of Claxton contains the following species:

Fauna of the Kinkaid Limestone Near Claxton

Triplophyllum spinulosum (M.-E. & H.).
Fenestella sp.
Polypora approximata Ulrich.
Orthotetes kaskaskiensis McChesney.
Diaphragmus elegans (N. & P.)

Camarophoria explanata (McChesney).
Girtyella indianensis (Girty).
Girtyella brevilobata (Swallow).
Spirifer increbescens Hall.
Eumetria vera (Hall).
Cliothyridina sublamellosa (Hall).
Composita subquadrata (Hall).
Aviculopecten sp.
Modiola sp.
Bellerophon sp.
Straparollus sp.
Phillipsia sp.

Correlation. The correlation of the Kinkaid is simply a matter of tracing the outcrop of the formation from place to place across western Kentucky and southern Illinois. The outcrop is discontinuous because of the extensive faulting, but the position of the limestone immediately beneath the Pennsylvanian sandstones, and its similar lithologic and faunal characters, renders its recognition and correlation certain.

CHAPTER V.

STRATIGRAPHIC GEOLOGY, PENNSYLVANIAN SYSTEM

Caseyville Formation

Introductory statement. All the strata of Pennsylvanian age which are exposed in the Princeton quadrangle are of Pottsville age, and so far as they have been examined in detail they belong to the Caseyville formation, although some representation of the Tradewater formation may be present in the extreme northeastern part of the area. No attempt has been made in the prosecution of the present work to make a complete examination of the Pennsylvanian area, the observations being limited to the establishment of the boundary between the Chester Series below and the overlying beds.

Name. The name Caseyville formation was applied to the lowest division of the Pottsville rocks as they are represented in this portion of western Kentucky by Glenn, from the town of Caseyville[1] in Union County, Kentucky. The name has since been adopted for the equivalent strata in southeastern Illinois, and will probably be applicable entirely across southern Illinois.

Lithologic character. The lithologic characters of the Caseyville are similar throughout the extent of the formation, there being several massive sandstone beds separated by thinly bedded, shaly sandstone, with more or less clay shale. The more massive beds stand out in many places as prominent bluffs, but the softer, less resistant beds are commonly more or less completely covered by talus accumulation.

In many places the more massive sandstone members of the formation are characterized by the presence of great numbers of rounded, white quartz pebbles, constituting veritable conglomerate layers, the pebbles varying in size from one-eighth of an inch to nearly an inch in diameter. The amount of the conglomerate varies greatly from place to place within the formation, but even where the quartz pebbles are lacking entirely, the Pottsville sandstone cannot be easily mistaken for any of the

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[1] Coal of the Tradewater River Region, Ky. Geol. Surv., Bull. No. 17.

Chester sandstones, because of its coarser texture. The most conspicuous conglomerate beds seems to be present where the pre-Pottsville unconformity is the greatest, as in the region about Claxton.

Coal. No extensive coal mining has been attempted at any locality in the Princeton quadrangle. Thin coal seams are present locally and in a few places have been worked a little for local consumption.

Distribution. The greater portion of the Pottsville rocks in the Princeton quadrangle is confined to the northeastern portion of the area. The boundary of the formation starts near the middle of the northern boundary of the quadrangle, and continues southeasterly in a sinuous line, interrupted in places by faulting, to the eastern border of the quadrangle east of Claxton.

Besides this main area of Pottsville in the quadrangle, the formation is present in a number of the down-dropped fault blocks in different parts of the area. The largest of these blocks lies chiefly in the extreme northern portion of the Claxton and Princeton rectangles, and extends in a nearly east-west direction between faults 6, 7, 33, and 3, with a maximum width of over one mile in the northeastern part of the Princeton rectangle. Most of the other down-dropped blocks of Pottsville are present wholly or in part in the northren half of the Princeton rectangle. The larger one lies south of Phelps Creek, bounded by faults 24, 25, 26, 28, and 17. In a narrow block about one and one-half miles in length, lying mainly between the two blocks already mentioned, and bounded by faults 24, 25, 33, and 3, the Pottsville caps the hills with the Kinkaid limestone exposed beneath. A small triangular block of Pottsville is present in the northwestern part of the Princeton rectangle, bounded by faults 22, 23, and 17. Two contiguous Pottsville blocks are present west and northwest of Princeton in the Princeton and Crider rectangles. These constitute some rough hills and are bounded by faults 33, 40, 41, and 42. Two other very small blocks have been recognized, one in the southwestern part of the Farmersville rectangle, bounded by faults 16, 17, 18, and 3, the second is in the Claxton rectangle, one-half mile southeast of Claxton, bounded by faults 58, 59, and 60.

Thickness. No accurate determination of the thickness of the Caseyville formation within the Princeton quadrangle has been attempted, but it can be safely estimated as being 400 feet or more.

Paleontology. No attempt has been made to collect the fossil plants from the Pottsville horizons in the Princeton quadrangle, although in some localities well preserved impressions of *Lepidodendron* trunks have been observed in the sandstones.

Correlation. Nothing new in regard to the correlation of the Pottsville of western Kentucky can be added from recent studies in the Princeton quadrangle. Floras from similar horizons elsewhere in this portion of the state and in southeastern Illinois, have been studied by David White, and his observations have led him to the conclusion that the Caseyville formation occupies a horizon near that of the Sharon conglomerate of western Pennsylvania.

CHAPTER VI.

STRATIGRAPHIC GEOLOGY, LAFAYETTE GRAVEL

Name. The youngest formation in the Princeton quadrangle, aside from the recent, surficial materials, is a gravel deposit, largely unconsolidated in character, which caps some of the higher hills in the western and southwestern portions of the area. These deposits doubtless represent the widely distributed formation to which the name Lafayette Gravel has been applied, although it is generally believed at the present time that gravels of different age and origin have been included under this name. The name may be used temporarily at least, for the deposits in the Princeton quadrangle, until all of the widely distributed similar gravels have been more thoroughly studied and are better understood.

Distribution. These gravel deposits occupy two distinct but strictly limited areas in the quadrangle at the present time. The first of these is west of Princeton, in the Crider rectangle, beginning on top of the ridge just east of White Sulphur Church, and capping the hills in a westerly and southwesterly direction for a distance of nearly four miles. The exact elevation of the base of this gravel formation cannot be determined with certainty, for the pebbles have been washed far down the slopes and into the stream valleys, in some places for two or more miles from their source. At White Sulphur Church the original deposits seem to lie at an elevtion of about 600 feet above sea level, but along the same ridge to the east, where it rises to an elevation above 600 feet, the gravel is apparently lacking. Three miles southwest of White Sulphur the base of the formation seems to occupy an elevation of about 640 feet. These elevations can only be considered as approximate, but where the pebbles are associated with the angular, residual cherts of the underlying formations, they are considered as having been washed down from their original position. Presumably the surface upon which the gravels were originally deposited was approximately a plane, and the differences in present elevation may be indicative of comparatively recent warping of the surface.

The second area of outcrop of the gravels is in the Saratoga rectangle, in the extreme southwestern corner of the quadrangle, on the hills west and northwest of Friendship School. In this area the elevation of the original deposits seems to be near 580 feet, which is somewhat lower than in the area described. Elsewhere in the quadrangle there are hills with similar elevations to those mentioned, upon which no gravel deposits are present.

Lithologic character. These hilltop gravels are made up of smoothly rounded chert pebbles, varying in size up to a diameter of four or five inches. The cherts which are represented in the deposits are various in character, but most of them are of such a nature as to suggest their origin from the St. Louis and Ste. Genevieve limestones of the immediate region. A small proportion of the pebbles, however, may have had a more remote origin. Most of the gravel seems to be wholly unconsolidated, but in places it has been cemented into an iron conglomerate or in a sand conglomerate. Masses of these conglomerates, some of them a foot or more in their dimensions, are common in the beds of ravines which head against the hills which are covered by the formation. In places the heads of these ravines are more or less completely filled in their beds, by a semi-cemented mass of these pebbles imbedded in red residual clay, which is more or less sandy in places. In most of such exposures there are a greater or less number of angular fragments of residual cherts from the underlying limestones, which suggest that these deposits are secondary from the original gravel accumulations.

Origin. The smooth, rounded character of the pebbles in these hilltop gravels show that they must have been formed by running water or by wave action along a beach. Neither running water nor wave action could place the pebbles in their present position upon the hilltops with the present topography. At the time when these gravel beds were laid down the present Princeton quadrangle, or at least some portion of it, must have been a part of a plane, the present hilltops occupied by the gravel being remnants of this plane, the present topography of the area having been developed since the period of gravel accumulation.

Age. The age of the gravel formation is doubtless the same as that of other widely distributed hilltop gravels which are present in the Ohio and Mississippi Valleys. Although there may be some difference in the time of accumulation from place to place, the age of most of the gravel deposits doubtless falls within late Tertiary time, and they are commonly considered as having been formed during the Pliocene period.

CHAPTER VII.

IGNEOUS ROCKS

Throughout the faulted region of western Kentucky and southeastern Illinois, a considerable number of igneous dikes have been observed. These dikes are commonly much weathered at the surface, and their residuum is commonly spoken of by the prospectors of the region as mica dirt. All of the dikes are basic in character, and those that have been studied petrographically have been identified as Peridodite or Lamprophyre, and all of the others are of the same general character. When fresh the rock is mostly dark in color, nearly black or with a greenish tint, although in a few places a lighter colored rock has been observed. In texture the rock is mostly very dense and compact, some occurrences of it being characterized by the presence of considerable amounts of black mica in flakes up to one-fourth of an inch in diameter. The rock is extraordinarily tough, when fresh, and difficult to break with a hammer. When weathered these dike rocks are soft and friable, commonly somewhat olive green or yellowish in color, and they give rise to a brownish residual soil which differs from the residuum of any of the sedimentary rocks of the region.

The origin of the dike rocks is totally different from that of the sedimentary rocks with which they are associated. Originally they were in the condition of molten lava which was injected into these sedimentary rocks from below, under great pressure. They undoubtedly connect, somewhere far beneath the present surface, with a great intrusion of igneous matter which perhaps extends as far as the limits of distribution of the dikes themselves, or farther. It is not possible to determine the depth of such an intrusion, for it has nowhere been penetrated by deep drilling or by mining operations, and is probably many hundreds of feet beneath the present surface.

Although the surface area occupied by the igneous rocks in western Kentucky is infinitessimal as compared with the sedimentary rocks, their importance is great, since the primary factor in the accumulations of the great deposits of fluorspar in the district has perhaps been the presence of this igneous intrusion.

Previously to the present field studies no dike rocks have ever been recorded from the Princeton quadrangle, the most numerous occurrences being in Crittenden County, but during the progress of the present work a dike has been discovered just west of the easternmost branch of Cany Creek, 1.1 miles southeast of Briarfield Church, and 1.5 miles north of Bethany Church. This dike is exposed in the heads of several short gullies. The exposure is not such as to permit the determination of its direction, but if the direction conforms with that of most of those in the district, it extends northwesterly and southeasterly. The rock itself is deeply weathered, and no fresh material whatever has been observed. In its present condition it is soft and friable and is just as easily eroded as the residual clays which are adjacent to it. The occurrence might not have been suspicioned except that the gullies were freshly cut when they were first visited. It is not improbable that numerous dikes may exist throughout this district which have never been observed because of their surficial covering, and for the same reason many of them may never be discovered.

CHAPTER VIII.

STRUCTURAL GEOLOGY

In common with the region to the west and northwest of the Princeton quadrangle, extending to the Ohio River and continuing beyond that stream into Illinois, the area included in this quadrangle is extensively faulted. This entire faulted district has an extent of 60 miles or more in an east-west direction, and over 50 miles in a north-south direction. The fault pattern throughout the whole area is remarkably complex, but scattered about locally there are small areas where the complexity of the faulting greatly exceeds that elsewhere. In the Princeton quadrangle the most complex of these areas lies southwest of Claxton, although a belt of more than commonly complex faulting continues northwestwardly across the quadrangle from the eastern border just south of Claxton to near the northwest corner.

Throughout the entire general area which has been mentioned the faulting is similar in character. The faults are in the main normal or tension faults, produced by the stretching of the earth's crust, and it is important to consider the source of the forces which caused the stretching. Scattered about through the faulted area there are a number of igneous dikes exposed. The exposures of these dikes are perhaps most numerous in the Ohio River bluffs, although they may be actually no less numerous elsewhere, the absence of surficial material upon the bluffs being responsible for their more common appearance. Where covered with the surficial materials the dikes are deeply weathered and are exposed only in a more or less accidental manner. During the summer of 1921 a previously unknown dike was discovered at a locality about five and one-half miles north of Princeton, in the head of a recently excavated gulley. This dike is much decomposed and its presence would never have been suspected except for the favorable location of the gully in which it is exposed. Doubtless there are scores of dikes throughout the faulted area which are completely hidden, and many of them may never be exposed to observation.

The presence of these scattered dikes through the faulted region suggest the presence of a deep seated igneous intrusion of wide extent, underlying the whole area. Such an igneous mass has never been penetrated by deep excavation or drilling, but its presence can probably be safely assumed, and its presence may be considered as being responsible for the bowing up and consequent stretching of the crust which has resulted in the faulting of the region. The fracturing of the crust by the stretching consequent to the intrusion, broke the rock strata into more or less wedge-shaped masses, varying greatly in dimension and form, some of them being only a few acres in extent, while others are square miles in area. All of the rock strata overlying the intruded mass must have been upraised by the lifting force of the intrusion, but the several wedge-shaped blocks produced by the fracturing of the strata slipped downward relative to each other in order to take up the slack produced by the crustal stretching. In places the downcrowding of the wedge-shaped blocks has produced sufficient lateral pressure to occasion small thrust faults of very minor importance, such as the one exhibited in Walche's cut, east of Scottsburg. Thrust faults of this character are of such small extent that they would never be detected except in a clean exposure such as is present in a fresh railroad cut or similar situation.

Associated with this complex faulted area of western Kentucky and southeastern Illinois, are the famous fluorspar deposits of the region. The more important of these deposits are in the form of more or less vertical veins along the faults. Fluorine is known to be a product of igneous rocks, and the fluorine content of the mineral fluorite doubtless was derived in some manner from the igneous magma underlying the region. Locally there are horizontal fluorspar deposits of limited extent, apparently filling solution cavities in the Ste. Genevieve limestone, which are probably secondary in origin as compared with the fault vein deposits.

The best exposure in the Princeton quadrangle exhibiting the characteristic faulting of the area, is in Walche's cut on the new line of the Illinois Central Railroad, between Scottsburg and Claxton a little more than one mile west of the last mentioned station. The faulting is also well exhibited along the old line of the same railroad, a mile or more southwest of Claxton. The accompanying graphic section of the strata exhibited in Walche's cut will serve to show the character of faulting in that exposure, where practically every formation of the Chester Series present in the quadrangle may be seen.

The amount and complexity of faulting in the Princeton quadrangle is evidenced by the fact that no less than 88 distinct faults have been mapped within its boundaries, but the faults are not uniformly distributed through the entire quadrangle. They are most numerous along a belt varying from one to three miles in width, extending across the quadrangle in a northwest direction from the eastern boundary south of the line of the Illinois Central Railroad, to the western border about half way between the line of the Evansville branch of the same railroad, and the northwestern corner of the quadrangle. Although the dominant direction of the faulting in this belt, established by the longer and more continuous faults, is northwest-southeast, there are faults within the belt whose direction lies in all points of the compass.

Other faults in the quadrangle, especially across its southern third, are nearly east-west in direction, and there are a number of east-west faults entering from the east, or crossing the main northwest-southeast belt. A number of faults northwest of Princeton diverge from the main belt of faulting in a southwesterly direction, and a similar northeast-southwest fault crosses the northwestern corner of the quadrangle at Flat Rock. Other southwest-northeast faults are present southeast of Scottsburg, connecting some of the more continuous east-west faults.

This whole fault pattern is markedly different, so far as the direction of the faults is concerned, from that exhibited in the Cave in Rock and Golconda quadrangles, north and west of the Princeton quadrangle, and in the continuation of the faulted area into Illinois, where the dominant direction is northeast-southwest, the direction being more northerly than in the case of the northeast-southwest faults in the Princeton quadrangle.

In addition to the many faults of the region, a well defined dome has been recognized in the area between faults 1 and 3, west of Farmersville. This Farmersville dome has been fully described in an earlier publication of the Survey.[1]

During the late summer and autumn of 1922 a well was drilled upon the Farmersville dome by the Atlas Oil Company, under the direction of their geologist, Mr. D. P. Hynes,[2] and the strata penetrated are as follows:

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[1] Ky. Geol. Surv., ser. 6, vol. 6, pp. 221-227 (1922).

Log of Well Three-fourths Mile West of Farmersville.

	Thickness	Depth
Soil	10	10
Tar Springs Sandstone (99 feet).		
Shale	25	35
White sandstone	74	109
Glen Dean Limestone (106 feet).		
Gray crystalline limestone	25	134
Gray shale with some limestone	55	189
Gray crystalline limestone	26	215
Hardinsburg Sandstone (35 feet).		
Gray to white sandstone	25	240
Gray sandy shale	10	250
Golconda Limestone (127 feet).		
Gray limestone	5	255
Gray shale with thin limestone layers	25	280
Gray limestone with some shale	61	341
Gray and black shale	8	349
Limestone and shale	8	357
Gray shale	5	362
Gray limestone	10	372
Shale and limestone	5	377
Cypress Sandstone (25 feet).		
Gray to green shale with sand	5	382
Gray to red shale	5	387
Fine red to gray sandstone	10	397
Greenish-gray siliceous shale	5	402
Paint Creek Limestone (95 feet).		
Gray crystalline limestone	30	432
Shaly limestone and siliceous shale	10	442
Gray crystalline and oolitic limestone	30	472
Dark calcareous shale	10	482
Gray crystalline limestone and shale	15	497
Bethel Sandstone (46 feet). Much gas.		
Fine, light gray to white sandstone	46	543
Renault limestone (61 feet).		
Compact and crystalline gray limestone with some shale beds	61	604

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[2] The writer is deeply indebted to Mr. Hynes for a very complete series of cuttings from this well. They were not available for study until after the preparation and submission of the present report, so that the findings could not be included in the discussion of the several Chester and other formations which have gone before. The importance of the data, however, warrants their consideration at this place.

	Thickness	Depth
Ste. Genevieve Limestone.		
Lower Ohara Member (28 feet).		
Compact to crystalline, partly oolitic, gray to white limestone	28	632
Rosiclare Sandstone Member (13 feet).		
Fine calcareous sandstone	13	645
Fredonia Limestone Member (371 feet).		
White oolitic and crystalline limestone	48	693
Fine white calcareous sandstone	5	698
Gray, yellow and white oolitic limestone with some chert	35	733
Fine gray calcareous sandstone	9	742
Gray to white, crystalline, compact and oolitic limestone with some chert	274	1016
St. Louis Limestone (335 feet).		
Light to dark gray crystalline and compact limestone with chert	144	1160
Dark gray to black limestone	128	1288
Black limestone	63	1351

This log has furnished important information concerning the thickness and lithologic character of the Chester formations beneath the Tar Springs Sandstone, and these thicknesses do not agree entirely with those determined from surface outcrops nor with the predictions made in the earlier description of the Farmersville dome.

The total thickness of the Tar Springs Sandstone is not represented in the well section, but all of the Chester formations subjacent to the Tar Springs have been penetrated. The Glen Dean limestone in the section has a thickness of 106 feet, while in the Walche's Cut section a thickness of 87 feet has been assigned to the same formation. On the other hand the Hardinsburg sandstone in the well section is 35 feet while in Walche's Cut 61 feet are referred to the formation. The combined thicknesses of the two formations, however, in the two sections are not very different, 141 in the well section and 148 in Walche's Cut. This would suggest that some of the higher portion of the Hardinsburg of Walche's Cut, that portion with calcareous layers in the sandstone and shale, should more properly be transferred to the Glen Dean limestone.

The 127 feet of shales and limestone of the Golconda formation are much thicker in the well section than in most other portions of the quadrangle. In Walche's Cut 80 feet of beds were included in the formation, and the minimum thickness of the formation seems to be as little as 30 feet. However this well section is the most westerly locality in the quadrangle where we have any knowledge of the formation, and still farther west in Crittenden and Livingston counties and in Illinois, the formation attains a much greater thickness in places, than that shown in the well record. This greatly varying thickness of the Golconda formation is doubtless due to pre-Hardinsburg erosion.

Information concerning the Cypress sandstone furnished by the well section conforms to that derived from a study of the surface outcrops in the quadrangle. The formation is only 25 feet in thickness and is very different in character from the massive sandstone which represents the formation farther west, both in Kentucky and in southern Illinois.

The Paint Creek limestone and the Bethel sandstone, as represented in the well section, conform closely with the surface outcrops of the same formations in the quadrangle, both in thickness and in lithologic characters.

The Renault limestone, 61 feet thick, is a little thinner in the well log than the estimated thickness of about 80 feet from surface outcrops, but it is difficult to determine from the well cuttings alone exactly where the line between the Renault and the Ste. Genevieve limestone should be drawn. This line has been assumed to be between the more shaly beds of the higher formation and the more or less oolitic limestone below. If the same section could be studied in surface outcrops it is possible that the line would have to be shifted somewhat.

The characteristic features of the Ste. Genevieve limestone are clearly shown in the well cuttings, the gray to white limestones with much oolite being a conspicuous feature. The Lower Ohara member is apparently about 28 feet thick. The Rosiclare sandstone member is entirely characteristic, with a thickness of 13 feet. A feature of the Fredonia limestone member, with a total thickness of perhaps 371 feet, is the presence of two thin, calcareous, sandstone beds beneath the Rosiclare, one 5 feet and the other 9 feet in thickness. A sub-Rosiclare sandstone member of the Ste. Genevieve limestone has been recognized at a number of localities in southern Illinois, but two such layers have not hitherto been observed. The total thickness of the Ste. Genevieve limestone, 412 feet, seems to be excessive. The line between the Ste. Genevieve and the St. Louis has been drawn below the last oolite, but it is even more difficult to recognize the line of separation between these two formations from the well cuttings than it is in surface outcrops where the fossils can be appealed to. There is no stratigraphic interruption in passing from one formation to the other, and the change in lithologic character is progressive.

The St. Louis limestone, as the log is interpreted, is represented by 335 feet of limestone, to the bottom of the well, which is probably near the base of the formation. The dark limestone of this portion of the section is characteristic of the St. Louis where the formation occurs in surface outcrops in this portion of Kentucky.

Manuscript completed Oct. 1, 1922.

The four following papers are separate and unrelated to each other or the preceding report which lends its title to this volume.

II.

RECENT CAVE EXPLORATIONS IN KENTUCKY FOR ANIMAL AND HUMAN REMAINS

By Arthur McQuiston Miller

Assistant Geologist

Explorations at Big Bone Lick. Upwards of a century ago interest in the remains of extinct animals and of man in Kentucky was much more pronounced than in recent years. Excavations at Big Bone Lick in Boone County for such remains—chiefly those of the mastodon—was a favorite pastime for such prominent personages as General William Henry Harrison (1795), Doctor Goforth of Cincinnati (1804), President Thomas Jefferson (1807), and John Clifford of Lexington (1816-17). Large numbers of remains of this extinct form of elephant—the mastodon—together with those of the buffalo belonging to living and extinct species, of the megalonyx—an extinct form of ground sloth—and of other herbivors which were attracted to such salines as this famous lick on account of the salt which there impregnated the soil, were exhumed as the result of these excavations and went to enrich the various museums of this country and of Europe. None of them remained in Kentucky.

Remains Found in Caves. Also remains were found in caves as the result of excavations carried on for saltpeter at that period. Some of these were human. With the decline of the saltpeter industry after the War of 1812, few instances are recorded of the finding of such remains, and interest in them languished.

Recent Cave Exploration. Prompted by a knowledge of what was formerly obtained from the caves of Kentucky and encouraged by the suggestions of a leading archaeologist—Dr. N. C. Nelson of the American Museum of Natural History, New York City—to the effect that on account of the similarity of position with reference to the glacial drift to the north, the caves of Kentucky should offer as good a field for archaeological exploration as those of France, the writer, in 1921, began some investigations on caves, first in the vicinity of Lexington and later in southern Kentucky—particularly in the county of Wayne. While the investigations have thus far not revealed the presence of undoubted remains of extinct animals in these caves, nor of those of man of a race more primitive than the American Indian, they have fully established the fact that the caves and rock shelters of Kentucky were for a long period frequented by both man and the lower animals contemporary with him, and that their remains have been preserved in them in abundance.

Caves of the Bluegrass Region

The caves near Lexington are in limestone of Champlainian (that is, lower Ordovician) age, this being the only limestone in north central Kentucky of sufficient purity for any great depth to readily dissolve by percolating underground water so as to form subterranean passages extensive enough to deserve the designation "caves." As this Champlainian, mainly Trenton, limestone forms by its outcrop the "Inner Bluegrass Region," it follows that these caves are confined in north central Kentucky to this distinctive physiographic district.

The Breck Smith and Phelps Caves. Two caves—the Breck Smith, eight miles west of Lexington on the Old Frankfort Pike, and the Phelps cave, four miles southwest of the city—have thus far proven to be the most favorable for exploration. From the former—a newly discovered cave which had previously escaped detection because filled to the roof with earth—have been obtained remains of the following mammals: raccoon, groundhog, gray fox (of a variety now extinct in the region), deer, buffalo, bear, dog or wolf, and man (Indian). Though doubtless some of these remains are of considerable age, estimated in years, none of them appear to date back of the present geological epoch.

In a recently discovered extension of the Phelps cave there was found a considerable portion of the skeleton of the black bear, which from the alteration it had undergone and the fact that it was cemented together in places with stalagmitic material, indicated for it a greater age than any of the remains found in the Breck Smith cave. It is probable that this bear dates back to the Pleistocene.

Quite recently a newly discovered cave on Jessamine Creek, not far from Wilmore in Jessamine County, has yielded some bone and teeth fragments which mark it as a place for further exploration. One of the teeth is the incisor of a very large beaver. The cave is in the Highbridge limestone.

CAVES OF SOUTHERN KENTUCKY

The cavernous limestone district of southern Kentucky abounds in caves and rock shelters which offer an attractive field for paleontological and archaeological exploration. During the summer of 1919 the writer, while making a geological survey of Allen County for the State Department of Geology and Forestry, discovered a rock shelter overlooking the Barren River containing Indian graves. Reference to this is made in the report on Allen County (Kentucky Department of Geology and Forestry, Series 5, Vol. 2, No. 3, pp. 220-242, 1919).

The Hines Cave. During the past summer the writer, while on a trip to Wayne County as guest of the Michigan Summer School of Geology with its camp on the Cumberland River at Mill Springs, had opportunity to examine the region for caves and rock houses containing human and animal remains. The one which offered the best prospect was a cave on the farm of Honorable J. S. Hines at Mill Springs. This cave, or more properly a ''rock house,'' with southwestern exposure, is 145 feet deep, 60 feet wide and 30 feet high. It is in a cliff of Ste. Genevieve limestone on the south side of a knob one and one-quarter miles due east of Mill Springs. It is evidently one of those ''dry caves containing human bones,'' which, according to Judge Haywood's History of Tennessee, published in 1823, the party of hunters under the leadership of Kasper Mansko (Mansker) found in this portion of Kentucky in 1769. This party, by some historians identified with the ''Long Hunters,'' but by others called the ''predecessors of the Long Hunters,'' here broke out of the forest through which they had been traveling since they left Virginia and North Carolina and saw stretching before them to the west a great grassy, treeless plain teeming with herds of buffalo, deer and other game. Unacquainted as yet with the French word ''prairie'' for such a treeless expanse, they called it ''meadow.'' This was the eastern end of the strip of treeless country in southern Kentucky and north-

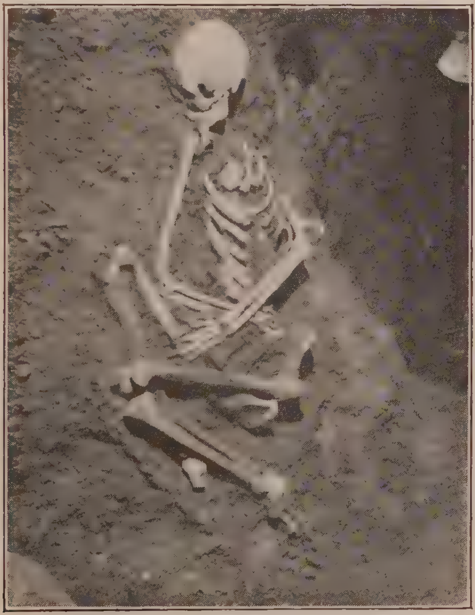
HINES' CAVE, NEAR MILL SPRINGS, WAYNE COUNTY, KY.

View showing site of removed stalagmite as seen from cave entrance. Photo by Arthur M. Miller, August, 1922

ern Tennessee, which later (by 1800) became known as the "Barrens." At the eastern margin of this strip these hunters established a central camp, called by them a "station camp," from which they radiated on hunting expeditions and to which they returned every five weeks to deposit their skins. The spring beside which the camp was established can still be identified. It is the family spring beside the home of Tilden East. It is one and one-half miles a little east of south of the J. S. Hines cave. The first permanent settlement of Wayne County, known as "Price's Meadow" or "Price's Settlement," was established here at least as early as 1797, for a map of Kentucky published between 1794 and 1797 by J. Russell has "Price's Settlement" marked upon it at this point. It is referred to under the name "Price's Meadow" by Judge Haywood in his History of Tennessee, above mentioned. The creek that drains this fine level tract of land extending to the foot of the mountains is still known as "Meadow Creek."

The floor of the Hines cave is covered with earth which contains a good percentage of nitrates (calcium and potassium nitrate 2.2 per cent) along with some phosphoric acid (1.49 per cent). As it contains in addition a large percentage (70.6 per cent) of acidity neutralizing calcium carbonate it would make a good all around fertilizer to spread upon land just as it is. The surface portion of this earthy accumulation was taken off during the Civil War and leached in the cave for the nitrates that it contained. Both the leached and unleached portions of this earthy material are filled with the bones of wild animals and the bones, implements and ornaments of humans (Indians).

In the deeper portions of the earth, that lying below the level removed for saltpeter manufacture, are whole skeletons of Indians whose bodies were placed there by burial. Evidence of thirteen of these distinct burials was obtained. Some of the skeletons were in an excellent state of preservation, and were exhumed practically complete. They are of persons of various ages from extreme youth to extreme old age, and of both sexes. Necklaces of shells (river gastropods) had surrounded the necks



INDIAN SKELETON IN BURIAL POSITION.

This skeleton was found three feet below top of earth floor, Hines' Cave, near Mill Springs, Wayne County, Kentucky. Photo by Dr. A. S. Hendrick, Oct., 1922.

of some of these—probably the females. Implements, both of stone and bone, and burnt clay utensils (pottery) had been buried with them.

The bones of the wild animals scattered through the earth in great profusion, from their broken condition, evidently belonged to those which were used for food by the inhabitants of this cave. All the long bones had been broken for the marrow and the skulls for their brain contents. These bones are now being studied in the Departments of Geology and Zoology at the University of Kentucky. So far, there have been identified from them those of mammals (deer, buffalo, bear, elk, raccoon, opossum, various rodents, including the beaver, wolf or dog, fox, wildcat, panther), birds (wild turkey, prairie chicken, crane), reptiles (land terrapin), fish (gar pike), and molluscs (river mussels and snails).

The bone implements found consist mainly of awls together with some needles. The former had been made from the cannon bones and ulnas of the deer. The stone implements consist of hoes (most numerous), skinners, pestles and arrow points. The last are of flint, the remainder are of the native limestone. The pottery—all in fragments—is a coarse variety made of mixed clay and crushed mussel shells which had been baked after being molded into form by being plastered on the inside of basketry. The ornaments found consist of shell beads and trinkets made from bone, mussel shell and stone, and of a piece of mica—the latter evidently imported from some point outside of the state.

It is evident that the mass of the accumulated material of this cave constitutes a large kitchen midden—Danish kjokkenmoddings (kitchen leavings)—and gives proof of very long residence of this rock shelter by the Indian inhabitants. Confirmatory proof of long occupation was furnished by a large mass of stalagmite which was removed from the middle of the front portion of the shelter. This mass of calcium carbonate, rising above the floor in a stool three feet wide and four feet high, was found to expand under the soft earthy floor to a diameter of about eight feet and to extend downward four feet. After removal of this mass weighing tons, by sledge, pick and crowbar, excavation was made to a still further depth of four feet without reaching the original rock floor. All through this mass and in the earth beneath, the same type of animal remains and articles of human workmanship were found as in the rest of the cave earth of this rock shelter. This stalagmitic mass was formed by deposit of lime from water slowly dripping from the roof. At present this roof drip takes place only after heavy rains.

The excavation in this cave was done during two trips, one in August, 1922, when for ten days the party camped near the entrance, and the other in October, 1922, when the party worked out from Burnside during a week-end. Associated with the writer in this work were the following persons: Professors W. S. Webb, J. Morton Davis, W. D. Funkhouser, J. K. Mitchell, and Messrs. J W McCollum and Leland Snoddy from the State University, Major Victor K. Dodge, Dr. A. S. Hendrick, Dr. W. E. Tait and William Lowry from Lexington, and Mr. C. F. Bales from Louisville.

Manuscript completed Nov. 15, 1922.

III.

A POTTSVILLE-FILLED CHANNEL IN THE MISSISSIPPIAN

By Wilbur Greeley Burroughs

Assistant Geologist

Kentucky contains an Eastern and a Western Coal Field. The Eastern, with an area of approximately 10,450 square miles, forms part of the west central portion of the great Appalachian Coal Field. The Western covers 4,680 square miles and lies in the Eastern Interior Coal Field.

These two coal basins of Kentucky are separated by formations of older geologic age. Northward from about North Latitude 37° 30″ the distance between the coal fields increases, the Ordovician, Silurian, Devonian, and Mississippian formations being at the surface in various areas. Southward from about this line, the Mississippian formations compose the bedrock except where some streams have cut down locally to the Devonian. The Cumberland, Fishing Creek, and a few other rivers have still further increased their channels and have exposed the Ordovician.

The shortest distance from the main body of Pennsylvanian strata of the Western Coal Basin to that of the Eastern Coal Basin is a straight line drawn from the main Pennsylvanian rocks of Hart County to the main body of these formations in Clinton County, a distance of about 64 miles. Measured to Wayne County, it is 70 miles, to Rockcastle County 90 miles. These measurements do not take into consideration outliers of small extent which will be referred to later.

Geologic history. The geologic history of the region under discussion shows why there has been some uncertainty as to whether or not the Appalachian and Eastern Interior Coal Fields were once connected over the present State of Kentucky.

Beginning at the close of Oswegan time of the Silurian System [1] movements of the rocks of the earth caused the strata to emerge from the sea in a low anticline. Due to this and subsequent folding, an arch was developed with its axis crossing the Ohio River from the State of Ohio into Kentucky at Point

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[1] Miller, A. M., Geology of Ky. Series 5, Bull. 11, p. 54.

Pleasant, about twenty miles above Cincinnati. Continued southward, the axis passes near Lexington. The anticline domes upward to its highest point in what is called the Jessamine Dome in the county of that name. From there it pitches southward to near the Kentucky-Tennessee boundary and then bows up into the Rutherford Dome of Tennessee.

During Mississippian times deposition extended westward and possibly covered the Bluegrass. At the close of this period the sea withdrew from a large part of the eastern interior, thereby exposing the sediments which formed dry land to the agents of erosion. In Kentucky the strata near the crest of the arch were worn away first. This beveling of the Mississippian strata caused the various formations to outcrop in belts. Deep channels were worn in the Mississippian rocks. In some localities softer shales and limestones overlying the Mammoth Cave limestone were entirely eroded away and the Mammoth Cave limestone itself cut into.

When the Pennsylvanian Period commenced, the advancing waters moving slowly westward from a region to the east of Kentucky, encountered a much eroded land surface intersected by river valleys. Upon this uneven surface were then laid down the basal rocks of the Pottsville formation.

In some places of the United States the Pottsville is composed partly of chert derived from the Mississippian limestone. This indicates the great length of time the Mississippian rocks were being weathered before the Pottsville was laid down. The Pottsville varies greatly in thickness due to irregularity of the surface of the underlying Mississippian formations, unequal rates and length of deposition, position relative to the shore line or river bank. The unconformity between the Mississippian and Pennsylvanian Systems spreads over a wide territory from Pennsylvania and Tennessee and Kentucky to Utah and Montana.[2]

With the continuance of the Pennsylvanian Period extensive swampy areas came into existence and coal began to be formed. At the close of the Pennsylvanian the State of Kentucky was elevated never again to be completely submerged.

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[2] Chamberlain, T. C. and Salisbury, R. "College Geology," p. 602.

The enormous period of time that has elapsed since the close of the Pennsylvanian has permitted extensive erosion to take place especially along the higher portions of the Cincinnati Arch in the Jessamine Dome. The result has been that the younger formations have been entirely worn away, exposing the underlying Ordovician strata and thereby forming the celebrated Bluegrass Region of Kentucky. The younger formations are being eroded away in a circle from the center thus ever widening the area of Ordovician surface rock. The Knobs of Kentucky now form the fringing margin between the main masses of Pennsylvanian formations and the Bluegrass territory. The present Eastern and Western Coal Fields owe their existence to being down on the flanks of the Cincinnati Anticline and thus they have not been eroded as rapidly as have the formations at or nearer the crest of the Arch.

But the question arises, did these two coal basins ever extend over the top of the Cincinnati Arch and unite to form one field? If they were united in Pennsylvanian times and since have been separated by erosion, may not there be some traces of their former surface area?

Prof. N. S. Shaler, W. M. Linney, W. T. Knott, A. M. Miller and others have stated their belief that the two coal fields once were connected.

Professor Shaler wrote:[3] "The Carboniferous conglomerate increases in thickness as we recede from the Cincinnati Axis. It contains a great quantity of pebbles, both in the east and in the west, but not a trace has yet been found of any pebbles which could be attributed to the Cincinnati axis.

"It is impossible to resist the conviction that a million of years ago, or thereabouts, this section still contained a continuous sheet of coal reaching from Wayne and Clinton Counties, on the east, across to Edmonson and Hart, on the west."

POTTSVILLE CONGLOMERATE IN ERODED MISSISSIPPIAN

Dr. W. R. Jillson, State Geologist of Kentucky, in May, 1922, directed the writer to map the Pottsville in certain areas of central and eastern Hart County and the adjoining counties of Larue, Green, Taylor and Marion, where an extended area of the basal formation of the coal measures was regarded as present. The writer started into the field at Munfordsville, Hart County, Kentucky.

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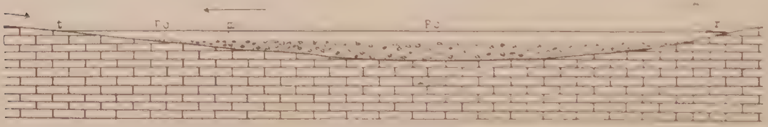
[3] Report of Progress, Shaler, Ky. Geol. Survey, 1877, p. 17.

At Munfordsville the surface rock is Ste. Genevieve limestone of the Mammoth Cave series, Mississippian System. The elevation at the Munfordsville Courthouse is 571 feet above sea level. Along this western outcrop of the Ste. Genevieve, it generally is a thick bedded oolite in which are interbedded layers of non-oolitic limestone. The thicker beds weather a distinctive white color. The Ste. Genevieve outcrops in a belt from the Ohio River in western Meade County southward to Tennessee, and east of the Bluegrass in a narrow strip from Tennessee to the Ohio River.[4] Monticello, Somerset and Mt. Vernon are along this outcrop.

Beneath the Ste. Genevieve comes the St. Louis limestone also of the Mammoth Cave series. It is chiefly a moderately thick bedded, fine grained, dark to black limestone. Blue and gray layers of fine texture occur. A distinguishing mark of the St. Louis is the quantity of irregular surfaced flattish pieces of chert it contains. Abundant chert debris is seen along the weathered outcrop of this formation. Also the St. Louis is non-oolitic. Thus it differs markedly from the overlying oolitic Ste. Genevieve. The St. Louis starts in Kentucky in Meade County at the Ohio River and stretches southward through



Section of Pottsville filled main channel and distributary. Shows main stream moving up original tributary, depositing pebbles and sand in both channels.

Horizontal scale 1 inch=½ mile.
Vertical exaggeration 8.8 times horizontal.
t—r=water surface of main river and its overbow into the tributary.
Pc=Pottsville conglomerate.
t=channel of tributary stream.
m=mouth of tributary where it joins main stream.
m—r=main river.
Mls=Mammoth Cave limestone in whose eroded surface are the channels of the main river and its tributary.
Arrows indicate direction of movement of water in main river moving up tributary, and flow of tributary stream before it reaches its ponded portion.

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[4] Butts, Chas. "Mississippian Series of Eastern Ky.," Ky. Geol. Surv., Series VI, p. 138.

Hardin, Larue, eastern Hart, northern Barren, eastern Warren and Simpson Counties. Its eastern outcrop is a rather narrow belt which extends through Clinton, Wayne, Pulaski (east of Fishing Creek), and Rockcastle Counties; northeast of Rockcastle County it is not so important and thins out entirely not far northeast of Frenchburg, Menifee County.[5]

Above the Ste. Genevieve the Cypress sandstone, Chester Group, Mississippian System, caps a number of the knobs lying near Munfordsville, and to the east. It usually is a thick bedded, gray sandstone. Butts states, that "in places it is thin bedded, has strongly cross-bedded layers, and that in the vicinity of Sample and Stephensport, Breckinridge County, it takes on a shale facies and has very little sandstone. Some of the shale is red, but most of it is green. The Cypress sandstone in Kentucky is mainly confined to the country west of the meridian of Louisville and north of the latitude of Bowling Green."[6]

The formations just described in west central Kentucky lie on the western flank of the Cincinnati Arch. The general dip is therefore westward. As one goes eastward, due to the beveling by erosion already referred to, older and older strata form the main surface rocks. Three and one-quarter miles north of Munfordsville, along the Louisville & Nashville Railroad, on the east side of the tracks, occurs a fault which has brought the Pottsville conglomerate down into the Mammoth Cave limestone. The limestone near the fault plane dips 24° northwestward toward the fault. About 300 feet south on the horizontal along the railroad tracks from the main fault a smaller fault has occurred, also bringing the Pottsville down into the limestone. The fault planes extend in a general northeast-southwest direction. The main block of faulted conglomerate extends northward along the Louisville & Nashville Railroad for about 3¾ miles. It forms the surface rock from the tracks to the top of the hills nearby. Massive Pottsville conglomerate was found near the summit of the high knob west of the tracks. Measured at right angles to the major axis of the faulted block of Pottsville rock, the width of the block is about $3\frac{1}{4}$ to $4\frac{1}{2}$ miles.

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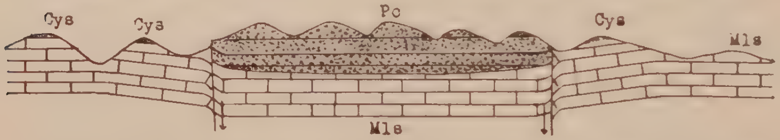
[5] Butts, Chas. "Mississippian Series of Eastern Ky.," Ky. Geol. Survey, Series VI, p. 125.

[6] Butts, Chas. "Mississippian Series of Eastern Ky.," Ky. Geol. Survey, Series VI, pp. 165-168.

About three-quarters of a mile north of Bonnieville, the north side of the faulted conglomerate is reached and Mammoth Cave limestone again becomes the surface rock from the railroad to the tops of the gently sloping hills, except where they are capped by Cypress sandstone. The topography resumes about the same aspect it had south of the faulted area.

West of the Louisville & Nashville tracks the writer mapped both sides of the down thrown Pottsville formation until it joined the main mass of the Pennsylvanian of the Western Coal Field. Mammoth Cave limestone country with wide valleys and comparatively gentle slopes border the rough area of the Pottsville block. The Pottsville varies in thickness from being entirely absent to 15 feet along the sides of the lens, up to 200 feet and over near the center. This doubtless is due to the sand and pebbles having been deposited in a deep channel eroded in the Mississippian formations. Then later the Pottsville filled channel was faulted downward. Near Cub Run, on a hill to the northwest of the Pottsville, the formations dip southeast toward the Pottsville at an angle of 20 degrees. On the southeast side of the Pottsville on the road from Cub Run to Munfordsville a brownish gray sandstone dips at approximately the same angle northwest toward the Pottsville lens. Thus the downthrow of the Pennsylvanian rocks caused the nearby surrounding formations to slant toward the fault area.



Diagrammatic section of faulted Pottsville filled channel in eroded Mississippian, west of Louisville & Nashville Railroad, Hart County, Ky. Note eroded surface of Mammoth Cave limestone on which the conglomerate rests. The Pottsville which originally extended on either side of the faulted area has been removed by erosion, as here illustratd.
Horizontal scale, 1 inch=1 mile.
Vertical exaggeration, 7.54 times horizontal.
Pc=Pottsville conglomerate.
Cys=Cypress sandstone.
Mls.=Mammoth Cave limestone.

About one-quarter of a mile east from the Louisville & Nashville tracks north of Bonnieville, on a road that leads ultimately to Hammonville, on the north side of the fault block, occurs a ledge of dark and light gray limestone with beds 3 to 4 feet thick. Total height above the road equals 20 feet. About one and one-half miles along this road to Hammonville, Pottsville pebbles occur approximately 50 feet vertically lower than the limestone just mentioned. Faulting and probably an erosion channel in the Mississippian, account for this position of the Pottsville in this small lens below the Mammoth Cave beds. Further along this road eastward occurs a small gravity fault. The Pottsville conglomerate, light gray oolitic Ste. Genevieve limestone and the darker gray, non-oolitic St. Louis limestone on the down-thrown side have been tilted on edge and brought down against other portions of the St. Louis. The distance across the edge, and hence the thickness of the Pottsville is 50 feet, the Ste. Genevieve 75 feet. Chert waste occurs on the St. Louis upthrow side of the fault. The fault plane extends in a general east-west direction.

On this same road occur red sand banks containing Pottsville quartz pebbles for a thickness of 40 feet. It is bounded at least on one side, where it can be seen, by dark gray, massive St. Louis limestone. It is a channel filling in the St. Louis.

Further on, on the outskirts of Hammonville, near the top of the hill above the stream in the bank beside the road occur Pottsville pebbles. Upon digging into the bank, it is found that beneath the weathered exterior the conglomerate became quite solid, although still weathered. The formation is distinctly cross-bedded and has the appearance of a delta formation. It probably is a small distributary from the main stream in the eroded Mississippian. Slightly down the hill is found the chert waste from the St. Louis. The St. Louis in the bed of the stream at Hammonville is dark gray, beds 2 to 3 feet thick, dipping 3 to 4 degrees toward the west. This St. Louis is very near the delta deposited Pottsville. If the Pottsville had been brought to its present position in this small lens by faulting, the St. Louis strata doubtless would have dipped at a greater angle than they do, and would have dipped with some relation to the position the Pottsville holds, but the St. Louis beds were inclined at the small angle mentioned, and slanted with no relation to the Pottsville. Hence the Pottsville acquired its present position as stated above.

From Hammonville to Magnolia cherty waste from the St. Louis is exposed beside the road.

On the southeast side of the large mass of Pottsville, east of the Louisville & Nashville tracks, patches of Pottsville pebbles occur along the side of the main Pottsville area. They are separated by Mississippian waste. In all cases only masses of Pottsville pebbles, at least 3 to 4 feet thick in situ, were mapped. Care was taken not to count loose pebbles which had been scattered by surface waters of the present day. The natives call the Pottsville quartz pebbles "Jack Rocks." About four-fifth of a mile west of Atna Furnace, Hart County, in the bank beside the road, weathered Pottsville pebbles and sand come in sharp contact with a cherty, gray, very hard limestone—the St. Louis. The curve of the contact resembles the bank of a small stream. The west side of this apparent channel filling was not exposed. North of Atna Furnace, toward Larue County, Pottsville pebbles, bounded by cherty limestone waste, occur. This sort of occurrence was noted frequently. The horizontal extent of the conglomerate pebbly deposit in these small channels varied from 20 feet to about 300 feet. Their long axis apparently ran in a direction that would meet the main body of the Pottsville. Even this main body of conglomerate was patchy in eastern Hart County in places.

The Pottsville in passing out of the northeast corner of Hart County cuts through the southeast corner of Larue County and extends in a narrow ridge, with spurs running off due to present stream erosion, along the boundary of Larue, Green, Taylor and Marion Counties. The conglomerate here is less weathered in places. The ridge forms the drainage divide between the tributaries of Rolling Fork on the north, and those of Green River on the south. The topography is very rough and wild. The people, influenced by this Pottsville topography, resemble the mountaineers of the main mass of Pennsylvanian formations many miles away. The conglomerate and its waste can be traced eastward for miles.

The distance from the end of the rather continuous Pottsville to the nearest Pennsylvanian strata of the Eastern Coal

Field is about 50 miles. Even after its continuity as a lens disappears, patches of Pottsville pebbles occur here and there from one coal field to the other.[7] Such patches of Pottsville waste were noted in Lincoln County and described by Linney in his "Report on Lincoln County," and by Prof. A. M. Miller in the Bulletin of the Geological Society of America, Vol. 20, 1908. Green River Knob, in the south corner of Casey County, is capped by the Pottsville sandstone.[8] The Cypress sandstone of the Mississippian, already mentioned as capping knobs, gives evidence of the fact that it once crossed the Cincinnati Arch and has since been isolated into outliers by erosion. The patches of Pottsville referred to above indicate that in the stream channel in which it was deposited, it also crossed the arch. The appearance of a stream channel filled with Pottsville sand and pebbles is somewhat more marked after one leaves the strikingly faulted portion to the west; although even there the fact that it is a channel filling is apparent.

Across the interval between the coal fields, somewhat northeast from the Pottsville filled channel which we have been following, in southeastern Madison County, is a valley worn in the Mississippian and filled with Pottsville conglomerate. This channel is at present, due to erosion, at the top of the knobs. Some of the pebbles are as large as hen eggs. Much cross-bedding occurs. This Pottsville disappears on the sides of this old valley, but increases not entirely as conglomerate, however, to 150 feet at the center. It is another Pottsville filled channel similar to the one running eastward from Hart County. The two fillings of Pottsville might have been dsposited from the same drainage system.

INFLUENCE OF THE POTTSVILLE-FILLED CHANNEL UPON THE LIFE OF THE PEOPLE

The stretch of rugged Pottsville conglomerate land flanked on both sides by Mammoth Cave limestone territory presents a striking contrast not only in topography but also in the life of the people. The limestone areas have been worn into wide, comparatively gently sloping valleys. The farmhouses and barns are well built on the average, and often painted neatly. The people appear comparatively prosperous. The main roads are piked.

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[7] Miller, A. M., "Geology of Kentucky," Dept. of Geol. of Ky., Series V, Bull. II, p. 200.

[8] Butts, Chas., "Mississippian of Eastern Ky.," Ky. Geol. Survey, Ser. VI, p. 166.

In contrast to this peaceful scene of the limestone areas, the narrow rugged Pottsville formation stretches like a wall, where it is well developed, approximately northeast-southwest in Hart County. Numerous streams have dissected the conglomerate into a rough, mature topography. The roads are often not much better than trails. They are nearly always ill kept, with great holes caused by washouts and ruts worn by the wagons of the mountaineers. One-room cabins and small box-houses are the rule. The people are poor and appear illiterate and shy. Their fields are small patches on the steep slopes of the unfertile soil, where they endeavor to raise tobacco and corn. Trachoma is present and frequently well developed, even to blindness.

The people are very courteous and hospitable once their inherent shyness is overcome. During the meals the mother and girls served the husband and his guest, as is done generally in the more remote parts of the southern Appalachian coal fields. Occasionally a cabin had its walls papered with newspapers. Everywhere the cabins were clean. The food in this Pottsville belt is typical of the mountains—eggs, soda biscuit, pork or bacon in gravy, and very strong coffee: Canned berries of many kinds were served, and butter, probably in honor of the company.

Prof. A. M. Miller, who was in a part of this area in 1908, writes that "It need awaken no surprise to learn that now and then a wild turkey may be seen, that the wildcat is not unknown, and the feud not uncommon. . . ."[9] The region offers an interesting problem for detailed geographic study.

CONCLUSION

The Pottsville conglomerate filled channel which we have traced northeast in Hart County and thence eastward toward the eastern coal field was probably formed as follows: (1) At the close of the Mississippian Period the land in Kentucky rose above the sea. The strata higher up on the Cincinnati Arch were worn away the most rapidly, causing the older strata to appear at the surface in belts. Numerous channels were worn in the Mississippian formations. In Pennsylvanian times waters of an alluvial fan advanced westward into Kentucky, slowly moving from regions to the east. These waters filled the erosional valleys in the Mississippian formations with sand and pebbles derived originally from Appalachia to the east.[10]

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[9] Miller, A. M., "Geology of Ky.," Dept. of Geol. of Ky., Series 5, Bull. 11, p. 201.

(2) In the case under consideration, two fresh water streams, the one flowing east and the other west, having their divide near the crest of the arch had eroded their drainage patterns in the surficial Mississippian. The Pennsylvanian waters in time filled these valleys and gradually passed over the main divide between them, forming one continuous coal measure stream flowing from eastern to western Kentucky. The waters of this large stream were impounded in the many branch valleys of the former streams until they overflowed through low passes into the lower lands and other tributaries which they found and then spread out as distributaries over the land surface. Sand and pebbles were laid down, filling the branch channels as well as the main river. The sand and pebbles were often deposited with cross-bedding. In some places larger rounded quartz pebbles were dropped and the finer sand sorted out, and to a great extent carried away. If the waters covered the land between the distributaries, they doubtless were not very deep and the sediments they deposited not very thick. Higher knobs of Mississippian formations may have stood as islands above the swirling waters. But a connection was made between what is now the Eastern and Western Coal Fields and, therefore, between the Appalachian and Eastern Interior Coal Fields, by the Pottsville sediments laid down in this great valley.

(3) The channel filled with Pottsville rock was subsequently faulted downward into the surrounding Mississippian formations. This aided in preserving the Pottsville from erosion, in addition to its favorable position in the channel carved in the Mississippian strata.

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[10] Graham, A. W., "Textbook of Geology," Part II, 1921, p. 479.

(4) At the close of the Pennsylvanian all of central and eastern Kentucky was elevated never to go beneath the water again. During this lapse of time the rocks near the crest of the Cincinnati Arch have suffered the greatest erosion Those situated farther down the sides of the fold and in the synclines have been more or less preserved. Today near the crest of the Arch only the channels filled with Pottsville remain. The more exposed limestone on the sides of the channels have been worn away, leaving the Pottsville channel fillings, where thick, standing up above the surrounding country.

(5) The Pottsville filled channel here described has influenced strikingly the life of the people who inhabit its areas. They resemble in all respects the people of the Pottsville country of the Eastern Coal Field. This ancient connection between the Eastern and Western Coal Fields, although obliterated in parts, still forms a connecting link by determining that the life of the people within its boundaries shall be that of the Pottsville coal fields.

Manuscript completed January 12, 1923.

IV.

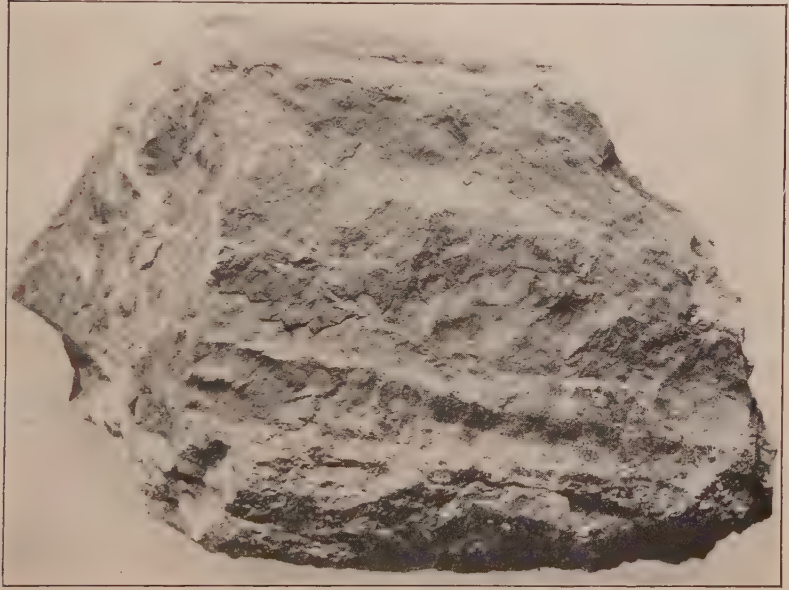
THE FLORA OF THE WESTERN KENTUCKY COAL FIELD

By Adolph Charles Noe

Paleobotanist

The Literature.

The fossil flora of the western Kentucky coal fields was first examined by Leo Lesquereux[1] in 1857. He describes the various coal seams which he studied and lists the fossils found with each one of them. Since that time our knowledge of fossil plants has considerably increased and the terminology of paleobotany has been somewhat revised and changed. His nomenclature does therefore no longer correspond, in many cases, with that of today, and his species names must be accepted with reservations. Otherwise Lesquereux's work is an excellent piece of paleontological research and a fine testimony to his knowl-



1. COAL BALL FROM WEST KENTUCKY MINE NO. 12.

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[1] Leo Lesquereux, Paleontological Report of the Fossil Flora of the Coal Measures of the Western Kentucky Coal Fields (Third Report of the Geological Survey in Kentucky, made during the years 1856 and 1857 by D. D. Owen, Frankfort, 1857, pp. 499-556, pl. VI, VII-.

edge of fossil plants. He was the great pioneer of paleobotany in the United States, whither he came with his fellow-countryman, the famous Louis Agassiz. In 1859 Lesquereux[2] continued his investigation of coal plants in Kentucky, extending it to eastern Kentucky as well.

2. IDEAL COAL-MEASURE SWAMP IN KENTUCKY.

Lester F. Ward[3] of the United States Geological Survey treats fossil plant deposits in Kentucky in a few pages of his large report on the geographical distribution of the fossil plants in North America.

Since that time only sporadic information on fossil plants was given in various short passages in the different bulletins of the Geological Survey of Kentucky.

THE CARBONIFEROUS PERIOD

The carboniferous period is divided in Kentucky as elsewhere in North America into the Mississippian and the Pennsylvanian Systems. The main bulk of the Carboniferous flora is found in the latter system because it contains the Productive

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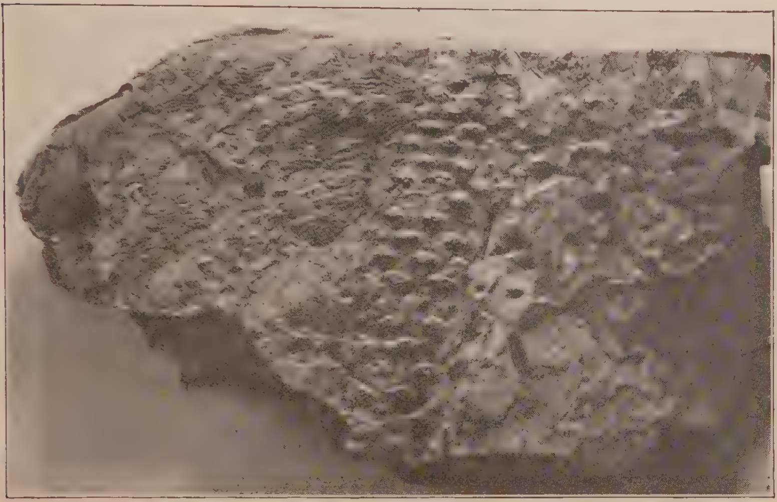
[2] Leo Lesquereux, Report of the Fossil Flora and of the Stratigraphical Distribution of the Coal in the Kentucky Coal Fields (Fourth Report of the Geological Survey in Kentucky made during the years 1858 and 1859 by D. D. Owen, Frankfort, 1861, pp. 333-437, pl. I-IV).

[3] 1889, Lester F. Ward, The geographical distribution of fossil plants (Eighth Annual Report of the U. S. Geological Survey 1886-1887 by J. W. Powell, Washington, 1889, Part II, pp. 663-960, pl. LXI.), Kentucky, pp. 882-884.

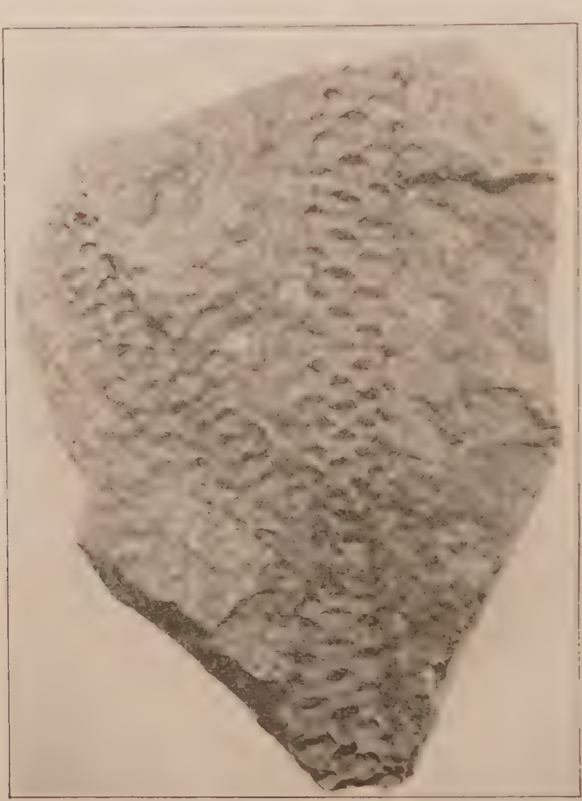


3. LEPIDODENDRON VOLKMANNIANUM FROM PRINCETON, KY.

Coal Measures, with their wealth of plant life. Only a few specimens from the Chester series of the Mississippian were collected during these investigations.

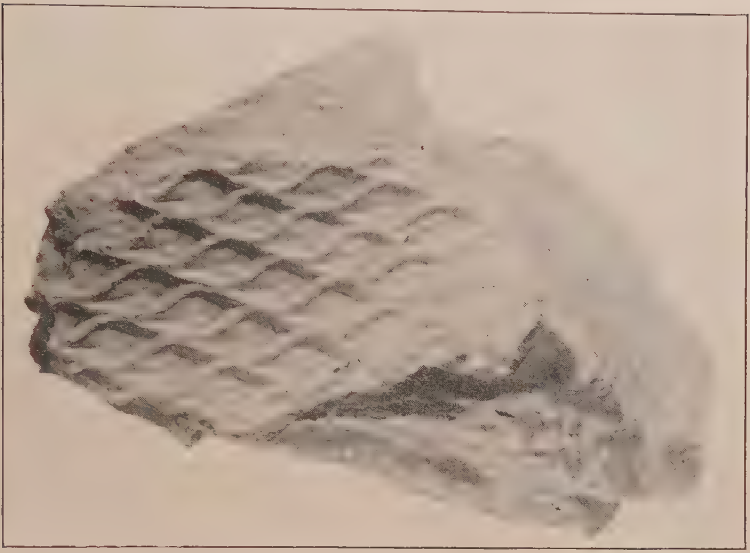
In the following a rather full picture of the Pennsylvanian plant life is attempted in order to familiarize the public with the principal types of the coal flora and to increase its interest and cooperation in future collecting expeditions.

The fossils appear either as petrefacts when the plant tissue is well preserved by impregnation with calcium and silicon or they are mere impressions and casts in the shale or sandstone. Petrefacts may be either petrified pieces of wood or coal balls. The former are found frequently in the fossiliferous strata, but coal balls had not been reported previously in American deposits. They are black or brown pieces of rock containing well-preserved stems, roots, fructifications, and leaves which had formed part of a coal producing layer of plant matter but were preserved as plant individuals by an early infiltration with lime or silicon.



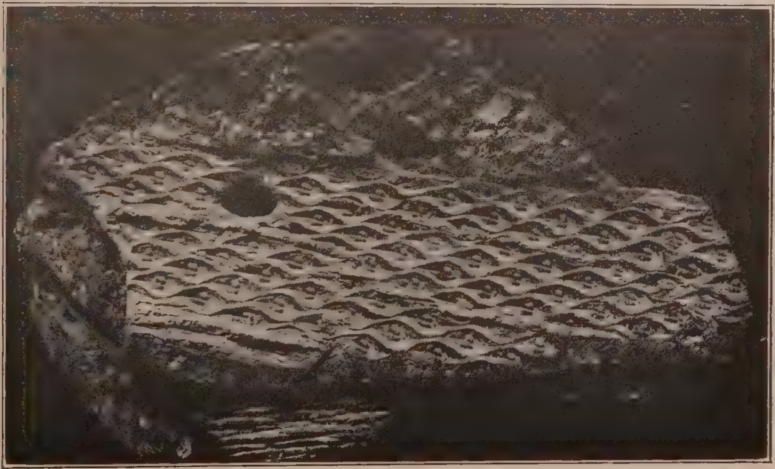
4. LEPIDODENDRON VOLKMANNIANUM FROM PRINCETON, KY.

Coal is metamorphosed and amorph plant matter, which shows cell structure only in rare circumstances under the microscope. But the coal ball can be cut and ground to microscope slices and will allow examination at a linear magnification of several hundred times, just like tissues of living plants. Therefore, coal balls are of greatest importance in fossil botany. They have revealed the wonders of paleozoic plant histology. Up to the present coal balls have only been found in England, France and the coal fields of Silesia and Moravia. The writer has been constantly on search for coal balls in this country. Many pyritic concretions (nigger-heads) occur in the coal, but the pure calcareous or siliceous type which is suitable for microscopic examination in transparent light could not be located.



5. LEPIDODENDRON VELTHEIMIANUM FROM PRINCETON, KY.

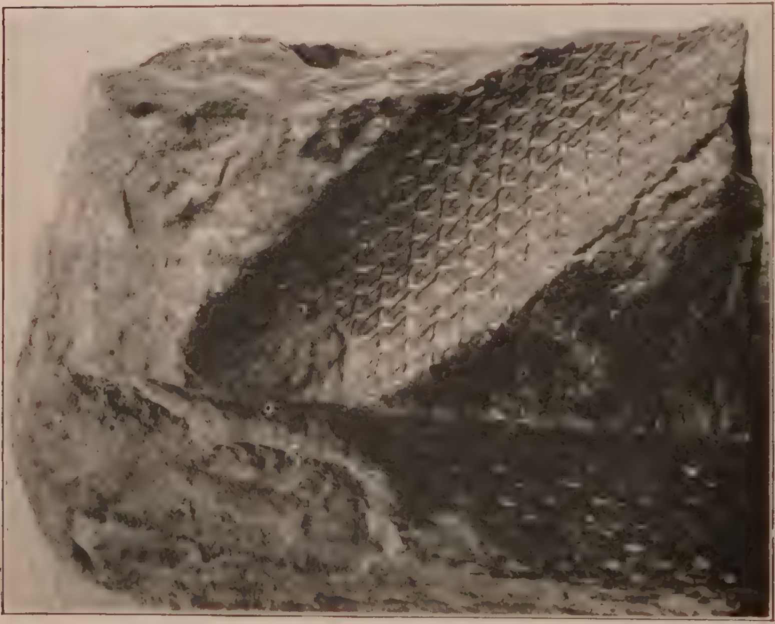
The first discovery of a real American coal ball occurred in Mine No. 12 of the West Kentucky Coal Company near Sturgis, Kentucky. The coal ball (Fig. 1) is unusually large as compared with the European material and promises to give valuable information when it will be cut.



6. LEPIDODENDRON VELTHEIMIANUM FROM PRINCETON, KY.

Since coal balls are calcareous concretions found in the coal seam they were rather expected to occur in the Kentucky coal No. 11 and the coresponding coal No. 6 of Illinois, which have a limestone cap rock. But the coal ball from Sturgis was found in coal No. 9 and similar coal balls were found in Illinois in coal No. 5 (O'Gara Mine No. 9 in Harrisburg). Investigation must therefore be prepared to look for such balls in these two corresponding seams of Kentucky and Illinois. There will be found, among the illustrations to this paper, some microphotographs obtained from English coal balls. They were taken by Dr. Paul Sedgewick in the botanical laboratories of the University of Chicago and prove the importance of this source of paleozoic plant material to science.

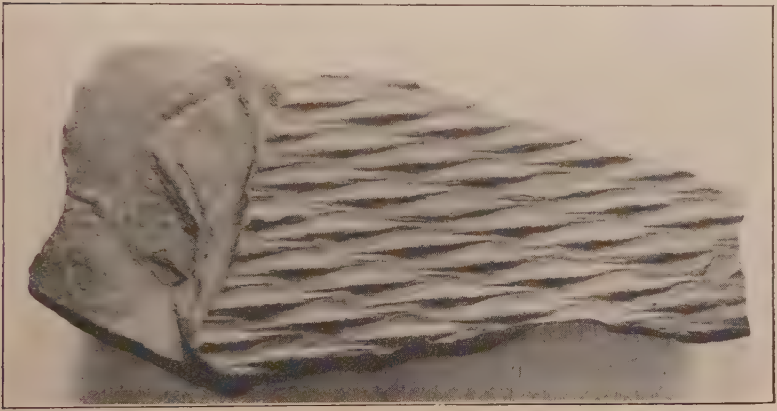
All illustrations of fossil plants are reproduced from originals which were collected by the writer or by other persons connected with the Walker Museum of Paleontology in the University of Chicago. The habit pictures of fossil plants were



7. LEPIDODENDRON FROM PRINCETON, KY.

taken by Dr. Lillian Reynolds of the University of Chicago. Wherever possible Kentucky fossils are presented, but in a few instances fossils from Braidwood, Mazon Creek, and Spring Valley in Illinois were included in order to illustrate the type of flora which covered the great basin of Kentucky, Illinois and Indiana in Pennsylvanian times.

The field work upon which this report is based began July 28, at the suggestion of Dr. W. R. Jillson, State Geologist, and ended August 27, 1922. Mines and outcrops were visited in Caldwell, Union, Henderson, Daviess, Webster and Hopkins Counties. Owing to the shortness of time a number of important localities in Hancock, Ohio, McLean, Muhlenberg, Breckinridge and Butler Counties could not be seen during this year's trip.



8. DECORTICATED LEPIDODENDRON STEM FROM PRINCETON, KY.

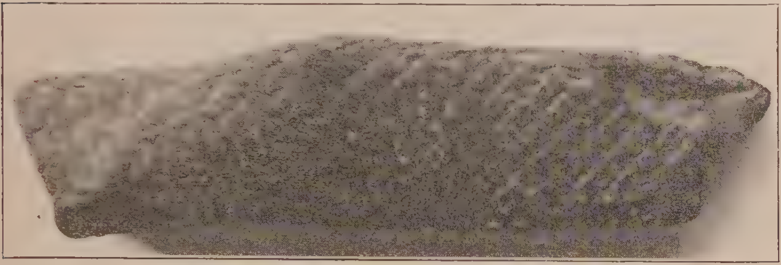
The Survey is indebted in many ways to the citizens of these regions generally for their cheerful cooperation in furthering the work and especially to the Hon. G. L. Drury of Morganfield, to Mr. J. C. Jenkins of Henderson, to the Bell Coal & Navigation Company, the West Kentucky Coal Company, the Morganfield Coal & Coke Company, the Southland Coal Company, and to numerous other corporations and individuals.

A Western Kentucky Coal Swamp During the Pennsylvanian Period

An ideal landscape showing the vegetation during the Pennslyvanian period in Kentucky gives us a startling picture (Fig. 2). Big trees which were probably over one hundred feet high, in many instances, form the bulk of the swamp forest. They belong to the extinct genera of Lepidodendron and Sigillaria whose surviving relatives are the small clubmosses (Lycopodium and Selaginella). These trees alternated with groups of gigantic horse tails (Calamites) of from twenty to thirty feet in height. Also some true Gymnospermic trees related to our pines and hemlocks were among the forest trees. The underbrush consisted of ferns and cycade-like, medium sized shrubs. The water currents are full of a, long since, extinct type of plants, the wedge shaped Sphenophyllum. Various climbing ferns cover the large trees and the open spaces in the thick forests are dotted with fern trees, some of which bore seeds.

9. DECORTICATED LEPIDODENDRON STEM FROM PRINCETON, KY.

This great swamp vegetation of western Kentucky, Illinois and southwestern Indiana grew at a low mean sea level and was frequently subjected to inundation. Sometimes the swamp was filled up with the stagnant waters of rivers when these were obstructed in their course by sandbars. In such a case it was a fresh water inundation. At other times the sea level rose and in the course of thousands of years the ocean water covered the swampy plains. More frequently it may have been the brackish water of the river deltas which flowed back into the land and covered everything with its salty floods. Whenever such an inundation occurred the rich vegetation was buried in sand and mud. Again the water level sank and a new vegetation occupied the emerged lowlands.

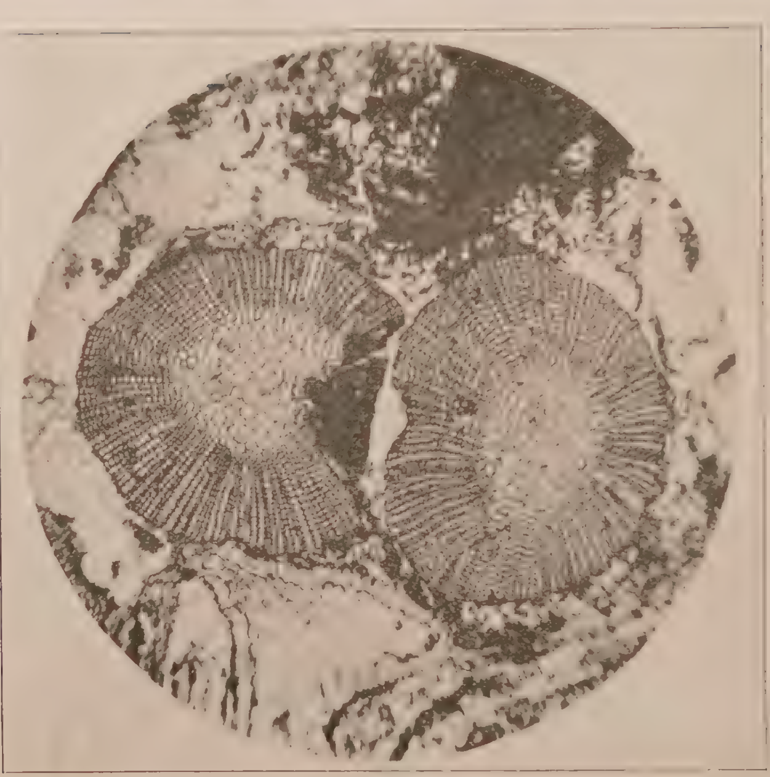


10. DECORTICATED LEPIDODENDRON STEM FROM PRINCETON, KY.

Submersions and emergions alternated successively many times and left as many layers of vegetable matter burried underground. The pressure of the overlying masses transformed the plant masses into coal, and a series of successive coal seams resulted. The plant structure disappeared in the coal, but many individual plants or plantorgans had been separated from the great mass and were buried in the sandstone or shale cover of the coal seam. They became imprints in the rocks, forming the roof of the coal, and in that way preserved their individuality. Other masses of vegetable matter were saturated with lime or silicon and became coal balls. Out of the impressions in the shales and sandstones and from microscopic sections of coal balls we have gained our knowledge of the vegetation which filled once the coal swamps of North America and we were able to reconstruct a picture of the swamp forests which once covered the basin of western Kentucky, Illinois and Indiana.

Plant Genera of the Western Kentucky Coal Field

A true conception of a coal swamp flora is best obtained by an examination of the fossil evidence. Herewith is given a description of the fossil types which lead to such a reconstruc-



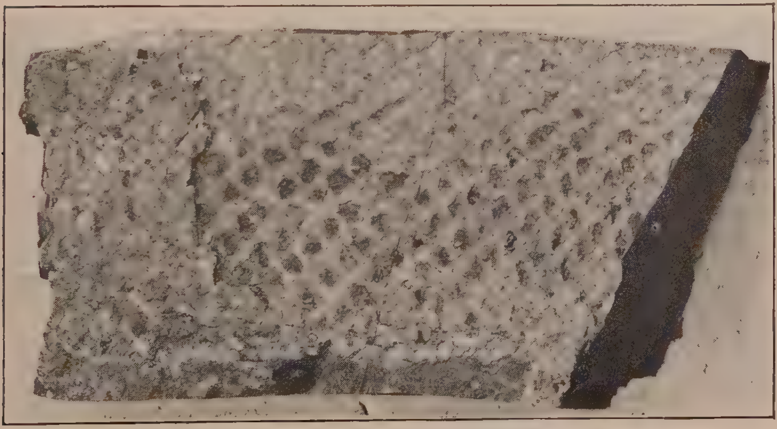
11. TRANSVERSE CUT OF BRANCHING LEPIDODENDRON STEM FROM COAL BALL.

tion. The types described were all found in western Kentucky in the course of the field work of last summer.

The largest tree forms belonged to two families represented by the genera Lepidodendron and Sigillaria. Lepidodendron means "Scale" tree because its bark looked like a fish scale. Figures 3 and 4 show an early type of Lepidodendron (L. Volkmannianum Sternb.) found in the Tar Springs sandstone, three and one-half miles northeast of Princeton, Kentucky. The scale-like bark appears very clearly. The leaf cushions forming the bark are still comparatively simple. The Tar Springs sandstone at the point where these fossils were taken lies below the Pennsylvanian or the so-called Productive Coal-Measures and is a member of the Mississippian series.

12. LEPIDODENDRON LEAVES FROM PRINCETON, KY.

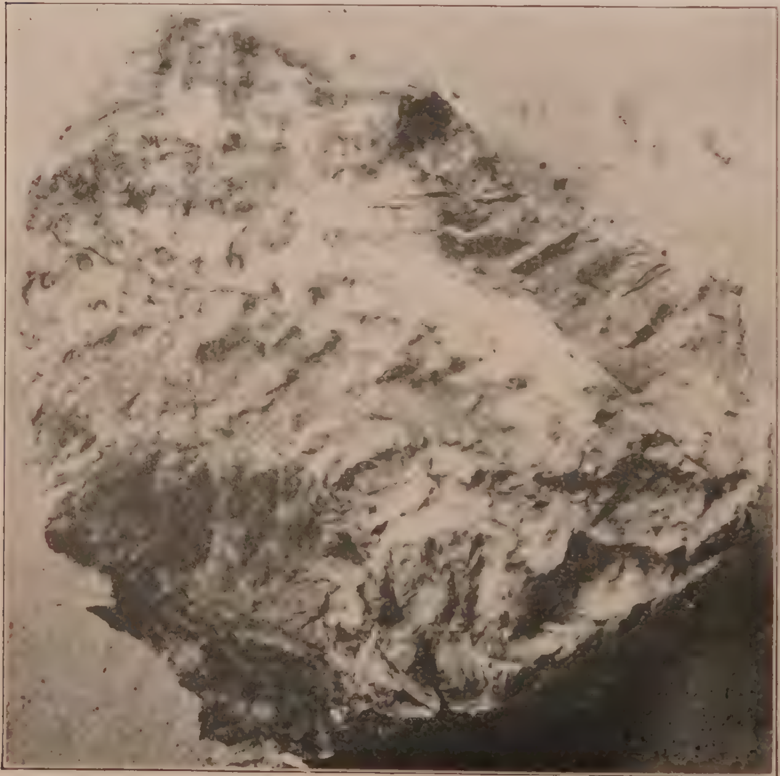
The design of the bark in Figures 5 and 6 is more ornamental. These photographs represent specimens of a Pottsville species (Lepidodendron Veltheimianum Sternb.). The Pottsville forms the lowest portion of the Pennsylvanian series. Figure 5, which is a positive cast, was found eleven miles northwest of Princeton, Kentucky, while a corresponding negative cast (Fig. 6) was picked up along the old road at the forking of Piney Creek, twelve miles southwest of Providence, Kentucky. Figure 7 shows a specimen from the same locality as Figures 3 and 4. The stem to the right is a well preserved cast of



13. SIGILLARIA STEM FROM EARLINGTON, KY.

Lepidodendron obovatum, Sternb., while the one to the left had suffered to a considerable degree decortication, which means the tree trunk had been washed about by current water and the outer bark or cortex had been shorn off before the specimen became embedded in the sandstone. Figure 8 represents another decorticated stem, probably from L. Volkmannianum, and was found in the same place with the specimens illustrated by Figure 5.

Decortication had proceeded so far in Figure 9 as to remove the entire bark of the specimen. In this instance the inner as well as the outer cortex is gone. The specimen was found on Piney Creek near the locality of the specimen shown in Figure 6. It is impossible to determine with accuracy the species of the specimen shown in Figure 9, but it might have been L. Volk-



14. STIGMARIA FUCOIDES FROM HENDERSON, KY.

mannianum. Another decorticated specimen, a cast of a small tree trunk which probably belonged to L. obovatum, is found in Figure 10. It comes from the same bed as Figures 5, 7 and 8. The Lepidodendron stem is divided dichotomously, that is, it branched by repeated forking. This is very well illustrated in a microphotograph taken from an English coal ball (Fig. 11). The leaves of Lepidodendron were lanceolate, somewhat resembling grass blades, and stood in tufts on the younger branches of the trees. Figure 12 represents a layer of these leaves, which was found in the same place with the specimen of Figure 3. To the ends of the young branches were attached the spore bearing cones of the Lepidodendron tree. They are rarely found.

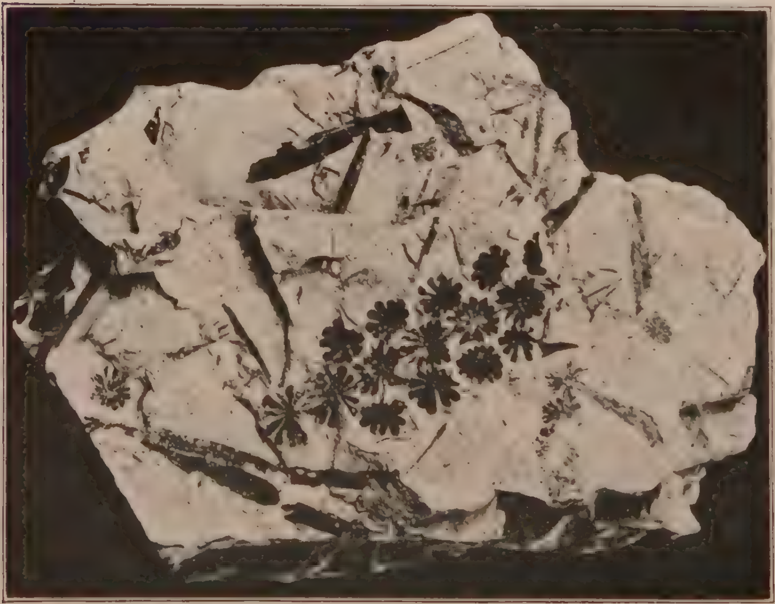
Similar in size was another great tree of the Coal-Measures, the Sigillaria or "Seal" tree, called so because its bark was covered with seal-like impressions. They formed vertical rows or spirals and were circular and hexagonal, while the Lepidodendron tree had rhomboid and diamond shaped scars. Figure 13

15. CALAMITES SUCKOVII FROM PRINCETON, KY.

represents such a Sigillaria bark. It was found on the coal slab in the North Diamond Mine of the St. Bernard Coal Company near Earlington, Kentucky. The outline of the scars appear in pyrite or iron sulfide on the black coal and make a very impressive fossil. In its branchings leaves and fructifications the Sigillaria resembles closely the Lepidodendron.

It is impossible to distinguish between the roots of Lepidodendron and Sigillaria. When first discovered they received the generic name of Stigmaria and only one species, S. ficoides Brongn., has been established. The Stigmarias are cylindrical casts characterized by a smooth or irregularly wrinkled surface bearing spirally disposed circular scars bounded by a raised rim and containing a central pit. Figure 14 shows an impression of S. ficoides from the Nicholson Mine at Henderson. The rootlets were attached to the small circular scars which supplied the tree with water.

The Stigmarias are often found to be of considerable length, frequently from 20-30 feet. They seem to have spread in four directions from the tree basis and have forked repeat-



16. ANNULARIA SPHENIPHYLLOIDES FROM BRAIDWOOD, ILL.

edly. They run close to the surface of the ground upon which the tree stood and were admirably adapted to support high trees in a mud soil.

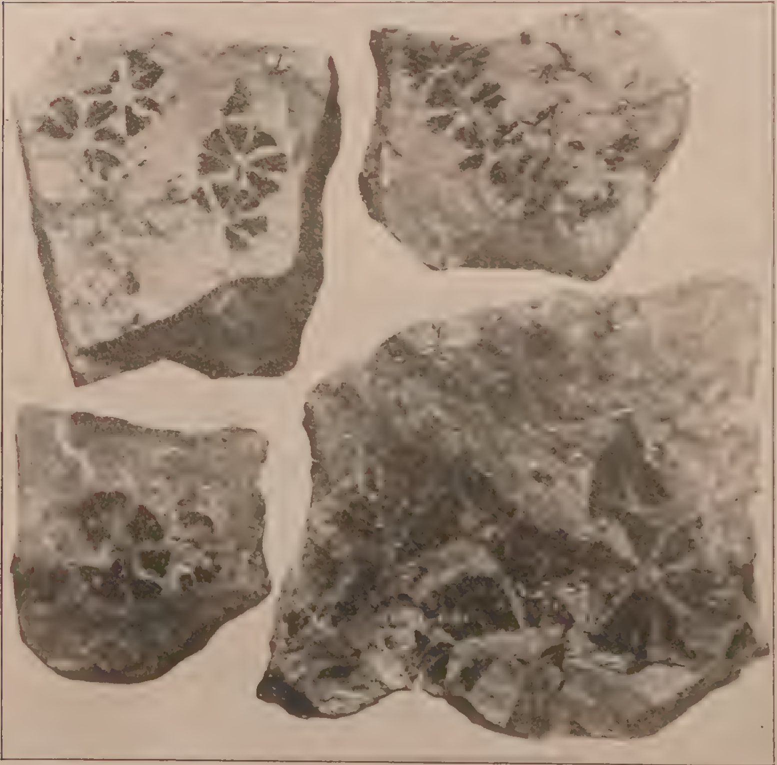
The Lepidodendron and Sigillarias were spore bearing cryptogamic trees nearly related to the club mosses of our time and formed with these the order of Lycopodiales.

Another recent plant group, the Equisitales or horse tails, were represented in the coal measures by gigantic tree forms. These ancient plants are now classified under the genus Calamites. A good specimen was found northwest of Flat Rock, near Princeton, Kentucky, and is shown in Figure 15. Calamites had, like the modern Equisetum, a jointed stem with branches radiating above the nodes. It grew up to a height of about 20-30 feet and was a swamp plant. The stem was born on an underground rhizome and was marked on the surface by longitudinal ridges and grooves. The leaves were attached to the branches in whorls or circles and were lanceolate or long and narrow.

The leaves of Calamites are usually described under the generic name of Annularia. Figure 16 shows a good specimen of Annularia Sphennophyloides Zenk which was found at Braidwood, Illinois.

17. SPHENOPHYLLUM EMARGINATUM FROM WEST KENTUCKY MINE NO. 7.

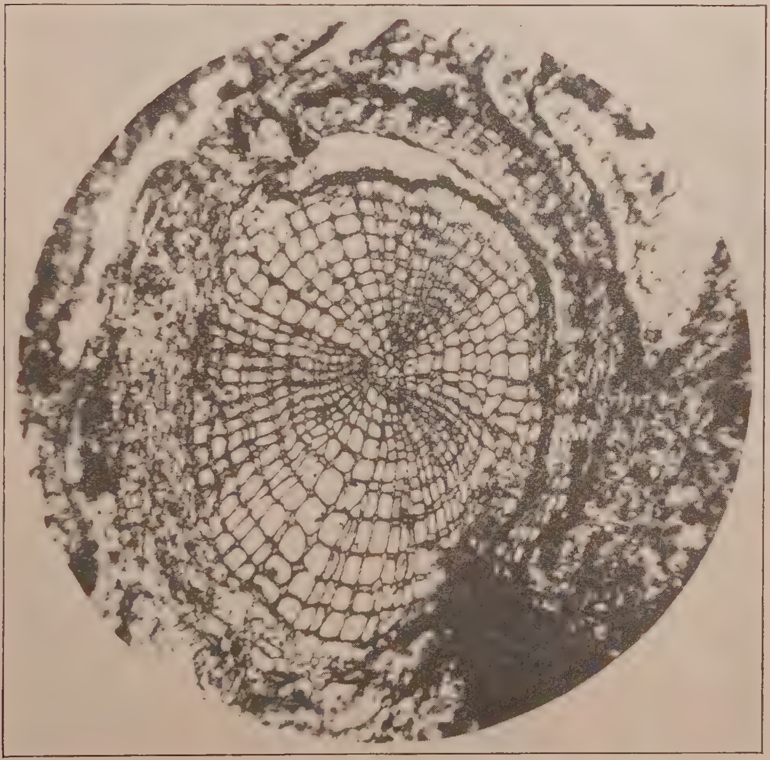
A completely extinct class of plants is represented by the genus Sphenophyllum. It has no living relatives. It seems to have been a water plant rooting in the bottom of ponds and creeks and consisted of floating stems with whorls of wedge-shaped leaves. Sphenophyllum means in Greek a wedge-shaped leaf. Figure 17 shows Sph. emaginatum, Brong., which was collected in Mine No. 7 of the West Kentucky Coal Company near Sturgis, Kentucky. Another specimen of the same plant from Braidwood, Illinois, is shown in Figure 18. Each whorl of the plant contains leaves in a multiple of three. The leaves are finely teethed at their broad end and the larger ones are usually more or less deeply divided by a medium slit. The stem was noded like that of Calamites, but had no ridges. It contained a triangular center from which rows of woody fibers



18. SPHENOPHYLLUM EMARGINATUM FROM BRAIDWOOD, ILL.

radiated. A microphotograph of such a stem, cut out of an English coal ball, is shown in Figure 19. No living plant has a similar arrangement of tissues.

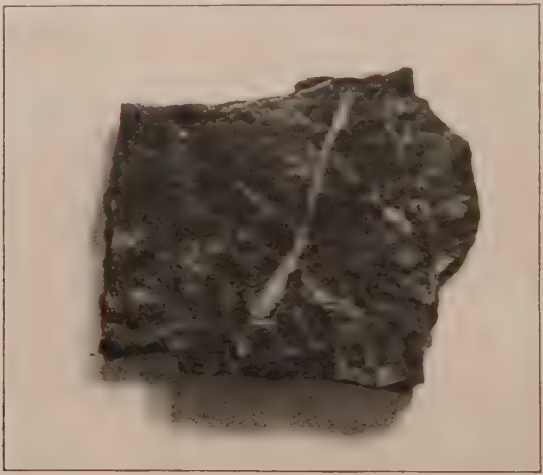
A great group of plants well represented in the vegetation of our time and very predominent in the Coal-Measures was that of the Ferns. Innumerable fossil ferns are known but few have been found until now in western Kentucky. The specimen represented in Figure 20 was collected with many similar impressions at the railroad crossing in Moorman, Kentucky, along the Livermore branch of the Louisville & Nashville Railroad. It belongs to the genus Neuropteris, but a more detailed determination is difficult on account of the poor state of preservation of the specimen. It is perhaps the same species (Neuropteris



19. SPHENOPHYLLUM STEM IN TRANSVERSE SECTION FROM COAL BALL.

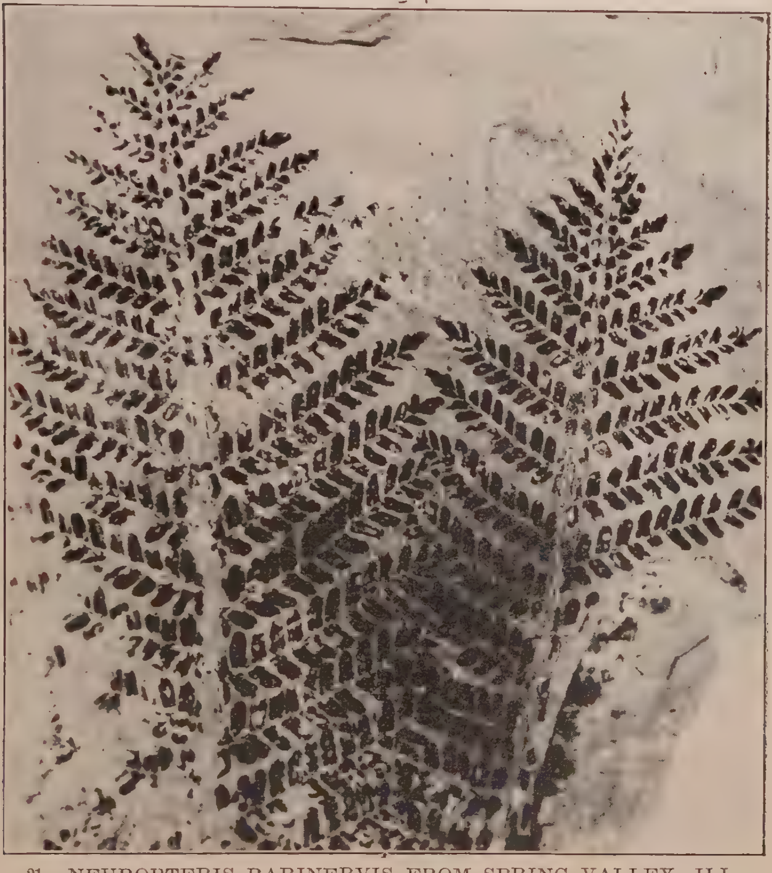
rarinervis) as represented in Figure 21 by a specimen found in Mine No. 1 at Spring Valley, Illinois.

When we examine fossil fern leaves from the Pennsylvanian system we rarely know whether we have true ferns or seed ferns before us. The latter group is now extinct, but had formed in the past a link between spore plants and seed plants. The seed ferns had a fern habitus, that is they looked in most respects like regular ferns, mostly tree ferns, but they bore seeds on certain leaves. Such a seed is shown in Figure 22 which represents a specimen (Physostoma) from Spring Valley, Illinois. An excellent microphotograph of a fern seed is shown in Figure 23. It is a longitudinal section of a Lagenostoma seed taken from an English coal ball. These seed ferns are now classified by American botanists, with the Gymnosperms, under the group name of Cycadofilicales, or Fern-Cycads. In England they are called Pteridosperms, which is a Greek translation for seed ferns.



20. NEUROPTERIS LEAVES FROM MOORMAN, KY.

The Cycadofilicales lead us to the great plant order of Gymnosperms, which is also represented in the Coal-Measures. The only genus which was found in Kentucky is Cordaites. Figure 24 shows a slab covered with Cordaites leaves which was found in the West Kentucky Mine No. 7 near Sturgis. A species determination is impracticable because of inadequate preservation.



21. NEUROPTERIS RARINERVIS FROM SPRING VALLEY, ILL.

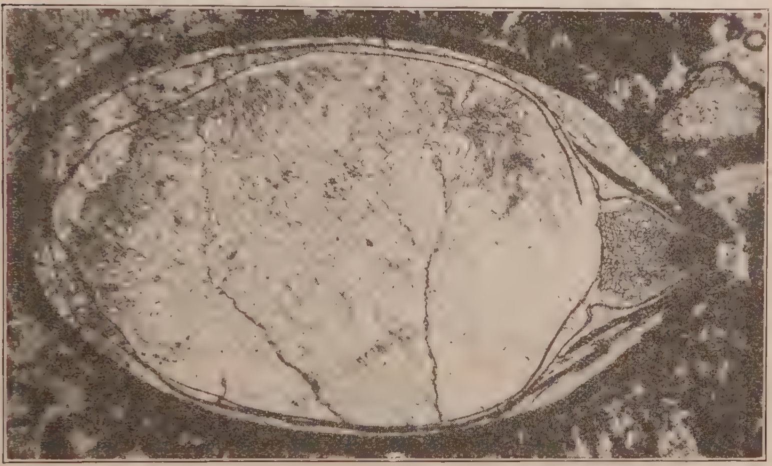
The above described groups characterize the flora of western Kentucky during Coal-Measure times. There were no flowering plants in existence at that time, nor palm trees. We know nothing about grasses and herbaceous plants because they did not lend themselves readily to fossilization. Only plants with deciduous leaves and with heavy woody stems could be preserved. It was a rather monotonous flora without bright colors. Green leaves and brown stems, possibly yellow spores, were in abundance. But after all it was a vegetation following very much the same biological laws as exist today. There must have passed more than a hundred million years since the time when coal was laid down in the Kentucky-Illinois-Indiana basin.

22. PHYSOSTOMA SEED FROM SPRING VALLEY, ILL.

Vegetation has changed since in details, but not in its fundamentals. How many hundreds of millions of years must have elapsed until the vegetation which we attempted to visualize in these lines had evolved cannot be fathomed by present day science.

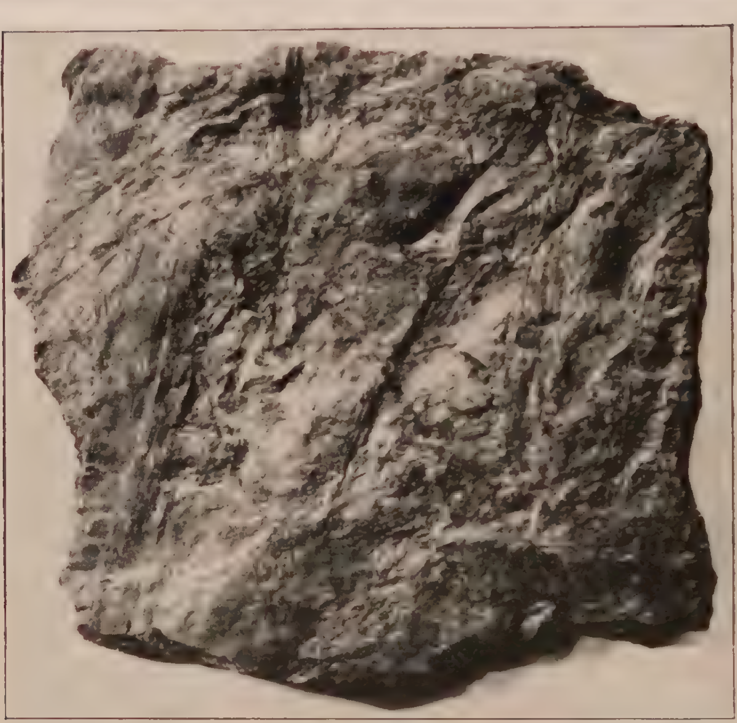
The Practical Value of Paleobotany

Naturally the question presents itself, what are the practical applications of the examination of fossil plants, as found with coal? Their knowledge is helpful in determining the different coal seams. It is often doubtful what coal seam may be under observation and the coal prospector wants to be certain. Also in deep shafts a new seam is frequently reached and its nature may be doubtful. A thorough study of the various floras of Kentucky, Illinois and Indiana seams is in progress, and with it a revision of the coal geology of these States.



22. LAGENOSTOMA SEED IN LONGITUDINAL CUT FROM COAL BALL.

A correlation of the seams in the great eastern basin of the Province of the Interior, the technical name of the coal field shared by the three States, should be helpful to the coal industry. At present the seams bear different numbers in the three States and often even in the same State they differ according to local ways of numbering. Each seam has its peculiar qualities, in heating value, in ash content, in humidity, all of which are factors of industrial importance. There are, of course, variations in the quality of coal even in the same seam. But entire seams were laid down under more or less uniform climatic, geographic, and biological conditions, and therefore tend to be rather homogeneous in quality. The great task of correlating the coal seams of our basin is merely in its beginning, and it should be brought to a more accurate conclusion by more



24. CORDAITES FROM WEST KENTUCKY MINE NO. 7.

research along these lines. A similar task has been accomplished for the coal basins of northern France, Great Britain and Upper Silesia.

Manuscript completed October 30, 1922.

V.

A BIBLIOGRAPHY OF THE MAMMOTH CAVE OF KENTUCKY

(Ninty-six Titles)

By Willard Rouse Jillson
State Geologist of Kentucky

During the past two or three years a number of new caves and caverns have been discovered in the Mammoth Cave region of Edmonson County, Kentucky. Several of these have been opened to the public by their owners, with the result that popular attention has been turned toward exploration of the caves of Kentucky as never before. A large percentage of the automobile tourists visiting or passing through Kentucky have come to plan cave trips en route. This class of visitors alone have increased annually by the thousands. This bibliography has been prepared and is now presented in response to a widespread and insistent demand for information as to the literature relative to the Mammoth Cave region. While there are literally hundreds of caves, large and small, in this karst section of Mississippian limestone in Southern-Central Kentucky, the following are the best known caverns. Popular names are given.

Mammoth Cave, Great Onyx Cave, Colossal Cavern, Hidden River Cave, Horse Cave, Crystal Cave, New Entrance to Mammoth Cave, Ganter's Cave, Dorsey Cave, Salts Cave, White's Cave, Dixon Cave, Proctor Cave, Long Avenue Cave, Preston Cave, Highland Cave, Indian Cave, Parker Cave, Doyle's Cave, Cave of the Hundred Domes, Mammoth Onyx Cave, Diamond Cave, and Cedar Sink Cave. Each of these caves exhibits characteristics differing from the others and all are quite worth while the time of the sightseer and explorer. All of these caverns are closely adjacent to the Louisville & Nashville Railroad and the Dixie (automobile) Highway.

ANONYMOUS.

***A Description of the Mammoth Cave of Kentucky, the Niagara River and Falls*, etc., 44 pp., J. M. Hewes & Co., Boston, Mass., 1850.

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